User's Manual
CPX
Probe Station

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LIMITED WARRANTY STATEMENT

WARRANTY PERIOD: ONE (1) YEAR

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Lake Shore has worked to ensure that the Model 340 firmware is as free of errors as possible, and that the results you obtain from the instrument are accurate and reliable. However, as with any computer-based software, the possibility of errors exists.

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Chapter 1: Introduction

1.1 General

This chapter serves as a brief introduction to the components that make up a complete testing environment with the CPX station at the core of that system. Also covered is a brief description of the testing environment and the types of applications for the probe station.

Features:

- High stability operation from 1.5 K to 475 K
- Sample can be maintained at room temperature while system cools, reducing potential for condensation
- Multiple radiation shields optimized to minimize cryogen consumption
- Sample stage with ±5° in-plane rotation
- Measurements from DC to 67 GHz
- Optional high vacuum to 10^{-7} Torr
- Optional load-lock assembly
- Accommodates up to 51 mm (2 in) diameter wafers
- Configurable with up to six thermally anchored micro-manipulated probe arms
- Probe arms with 3-axis adjustments and ±5° theta planarization
- Cables, shields, and guards minimize electrical noise and thermal radiation losses
- Options and accessories for customization to specific research needs

1.2 Product Description

The Model CPX is a versatile cryogenic micro-manipulated probe station used for non-destructive testing of devices on full and partial wafers upto 51 mm (2 in) in diameter. The CPX is a platform for measurement of electrical, electro-optical, parametric, high Z, DC, RF, and microwave properties of materials and test devices. Nanoscale electronics, quantum wires and dots, and semiconductors, are typical materials measured in a CPX. A wide selection of probes, cables, sample holders, and options makes it possible to configure the CPX to meet your specific measurement applications.

The CPX operates over a temperature range of 4.2 K to 475 K. With options, the base temperature can be extended down to 1.5 K. The probe station provides efficient temperature operation and control with a continuous refrigeration system using either helium or nitrogen. Vapor-cooled shielding optimizes efficiency and intercepts blackbody radiation before it reaches the sample. A control heater on the sample stage along with the radiation shield heaters provide the probe station with fast thermal response.

The CPX is user configured with up to six ultrastable micro-manipulated probe arms. Each arm provides precise 3-axis control of the probe position to accurately land the probe tip on device features. The sample stage provides in-plane rotation to allow alignment of patterns with stage axes. Proprietary probe tips in a variety of sizes and materials minimize thermal mass and optimize electrical contacts to the device under test (DUT). Probe tips are thermally linked to the sample stage to minimize heat transfer to the DUT.

For increased versatility, CPX options include temperatures down to 1.5 K, high vacuum, load-lock assembly, vibration isolation systems, LN_2 Dewar kit, higher magnification microscope, turbo pumping system, and optical fiber assembly.

1.2.1 Applications

- Electrical and electro-optical measurements over a wide temperature range
- RF and microwave
- Parametric testing
- Shielded/guarded/low noise characterization
- High Z
- Non-destructive, full wafer testing

1.2.2 Materials

- Nanoscale electronics (carbon nanotube transistors, single electron transistors, molecular electronics, nanowires, etc.)
- Quantum wires and dots, quantum tunneling
- Single electron tunneling (Coulomb blockade)
- Basic semiconductor devices including organics, LEDs, and dilute magnetic semiconductors

1.3 Specifications

1.3.1 Temperature

Operating temperature range—overall	1.5 K to 475 K*
ZN50 DC/RF probe with low RF cryogenic coaxial cable	1.5 K to 475 K*
ZN50 DC/RF probe with high RF semirigid coaxial cable	1.5 K to 475 K*
GSG microwave probe with semirigid coaxial cable	1.5 K to 475 K*
Temperature control (heaters)	
Sample stage	50 W
Radiation shields	Two 100 W and one 50 W
Probe arm	Measurement only

** Selectable equipment*

TABLE 1-1 ***Temperature***

1.3.2 Probe Arm and Sample Stage Adjustments

Travel	
X axis	51 mm (2 in)
Y- axis	25 mm (1 in)
Z-axis	18 mm (0.7 in)
Translation scale	
X-axis	20 µm
Y and Z-axes	10 µm
Planarization*	±5°
Sample stage (sample holder) in-plane rotation	±5°

Included with microwave probes

TABLE 1-2 ***Probe arm adjustments***

1.3.3 Frequency Range

ZN50 DC/RF probe frequency range	
Tungsten with cryogenic coaxial cable	0 to 50 MHz*
Tungsten with semirigid coaxial cable	0 to 1 GHz**
Paliney 7 with cryogenic coaxial cable	0 to 50 MHz*
Paliney 7 with semirigid coaxial cable	0 to 1 GHz**
BeCu with cryogenic coaxial cable	0 to 50 MHz*
BeCu with semirigid coaxial cable	0 to 1 GHz**
GSG microwave probe frequency range	
Low frequency with K connector	0 to 40 GHz*
Mid frequency with 2.4 mm connector	0 to 50 GHz*
High frequency with 1.85 mm connector	0 to 67 GHz*

**Selectable equipment*
***S21>-10 dB up to 1 GHz, except for a (-40 dB) spike between 400 MHz and 800 MHz depending on probe model and placement; S11 < -3 dB up to 1 GHz*

TABLE 1-3 **Frequency range**

1.3.4 Optical

Optical viewport—located on top lids	Ø54 mm (2.13 in) outer window and Ø50 mm (2 in) inner window
Outer, clear fused quartz	99% IR transmittance
Inner	IR absorbing with narrow band visible light transmittance
Optical resolution—-microscope	
7:1 zoom	4 µm
16:1 zoom	4 µm*

**Selectable equipment*

TABLE 1-4 **Optical**

1.3.5 Sample Holder

Maximum sample size—overall	Up to Ø51 mm (2 in)
SH-1.25-G, grounded sample holder	Up to Ø32 mm (1.25 in) and 475 K
SH-1.25-I, isolated sample holder	Up to Ø32 mm (1.25 in) and 400 K*
SH-1.25-C, coaxial sample holder	Up to Ø32 mm (1.25 in) and 400 K*
SH-1.25-T, triaxial sample holder	Up to Ø32 mm (1.25 in) and 400 K*
SH-2.00-G, grounded sample holder	Up to Ø51 mm (2 in) and 475 K*
SH-2.00-C, coaxial sample holder	Up to Ø51 mm (2 in) and 400 K*
SH-2.00-T, triaxial sample holder	Up to Ø51 mm (2 in) and 400 K*

**Selectable equipment*

TABLE 1-5 **Sample holder**

1.4 Standard Equipment

Flow cryostat	4.2 K to 475 K
Sample stage temperature sensor	Lake Shore Model DT-670-SD-1.4H calibrated silicon diode
Sample stage heater	50 W
Cooled radiation shield and cooled IR-absorbing window above the sample	
Radiation shield temperature sensors	Three Lake Shore Model DT-670C-CU silicon diodes
Radiation shield heaters	Two 100 W and one 50 W
Removable top lid with viewport	Ø50 mm (2 in) window
Temperature controllers	One Lake Shore Model 340 with 3462 expansion card, one Model 332S, and one Model 142 200 W (2 channels, 100 W each) power supply (independent regulation of sample stage, radiation shields, and probe arm temperature monitoring)
Electroless nickel-plated aluminum vacuum chamber	
Diameter	279 mm (11 in)
Removable top lid with clear fused quartz viewport	Ø54 mm (2.13 in) window
Probe ports	6 surround the sample thermal radiation shield
Pump port	NW 40 (pump sold separately)
Gas purge and 0.5 psi safety pop-off port	NW 25
Option port	High vacuum
Spare ports	NW 40 and NW 25
Machined aluminum base plate	610 mm × 737 mm (24 in × 29 in)
Support stand	Heavy duty welded steel stand—optional pneumatic vibration isolation system available
Temperature sensor installed and wired to a 6-pin feedthrough (included on one probe arm)	
Grounded sample holder	SH-1.25-G, accommodates up to a Ø32 mm (1.25 in) sample with a Ø25 mm (1 in) probe area
Optics	
Zoom 70 microscope	7:1 zoom with 4 μm resolution
Color CCD camera	S-video or composite output format
Swing arm	Optics can be manipulated to view any part of the sample or wafer, and can be retracted and swung away to allow access to the top of the vacuum chamber for sample exchange
Video monitor	High resolution, 17-inch
Sample illumination	Coaxial via optical fiber or ring light from an adjustable light source and power supply (must specify sample illumination at time of order) **NOTE: Coaxial illumination is recommended for highly reflective materials**
High efficiency helium transfer line with foot valve for precise flow regulation	
Instrument console	
Basic tools and spares kit for standard operation	

TABLE 1-6 ***Standard equipment***

1.5 Required User Configurable Equipment

Micro-manipulated Stages, Probes, Probe Tips and Cables
We understand that today's researcher requires flexibility. Our wide selection of probes, cables, sample holders, and options make it possible to configure a probe station to meet your specific measurement applications.

1.5.1 Up to Six XYZ Precision Micro-manipulated Stages

Part Number	Description
MMS-09	Micro-manipulated stage with thermal radiation shields, stainless steel welded bellows, and feedthrough ports—includes probe arm and base; probes, probe tips and cables sold separately

TABLE 1-7 ***Micro-manipulated stage***

1.5.2 ZN50 DC/RF Probes

The ZN50 DC/RF probes are ideal for DC biasing, low/high frequency measurements, low noise shielded, and low-leakage guarded measurements. The ZN50 probe base incorporates a pair of copper braids that anchor to the 4 K stage to minimize heat loss. The SMA connector is mounted directly to a replaceable alumina ceramic blade with a 50 Ω stripline routed to the probe contact.

The following tables provide specifications for the ZN50 DC/RF probes. You can find more information on the ZN50 DC/RF probes in section 2.3.2 and application information in section 2.4.

Part number (probe body)	Description
ZN50-55I	50 Ω stripline probe body mount requires a ceramic blade—selectable below

TABLE 1-8 ***ZN50 probe body***

Part number (ceramic blade)	Tip material	Maximum frequency (GHz)	Tip radius (µm)
ZN50R-03-W	Tungsten	1 *Maximum frequency 50 MHz with ZN50-G or ZN50-T cable; maximum frequency 1 GHz with MWC-09-00K-NM cable*	3
ZN50R-10-W			10
ZN50R-25-W			25
ZN50R-03-P7	Paliney 7		3
ZN50R-10-P7			10
ZN50R-25-P7			25
ZN50R-03-BECU	BeCu		3
ZN50R-10-BECU			10
ZN50R-25-BECU			25
ZN50R-100-BECU			100
ZN50R-200-BECU			200

TABLE 1-9 ***ZN50 probe tips***

1.5.3 ZN50 DC/RF Cables

Part number	Cable type	Connector type	Feedthrough type	Measurement configuration	Maximum frequency	Maximum temperature
ZN50-G	Ultra-miniature cryogenic coaxial	SMA	BNC	Shielded	50 MHz	475 K
ZN50-T	Ultra-miniature cryogenic coaxial	SMA	2-lug triaxial	Low leakage	50 MHz	475 K
MWC-009-00K	Semirigid microwave coaxial	K (SMA compatible	Loss-less compression seal	High frequency	1 GHz*	475 K

** S21 > -10 dB up to 1 GHz, except for a (-40 dB) spike between 400 MHz and 800 MHz depending on probe model and placement; S11 < -3 dB up to 1 GHz*

TABLE 1-10 ***ZN50 DC/RF cables***

1.5.4 GSG Microwave Probes

- Coplanar waveguide probe with ground-signal-ground (GSG) contact geometry
- User-specified pitch (spacing)
- Optimized low thermal conductivity coaxial leading to low thermal conductivity tips
- Include a copper braid assembly to cool the probe to near sample temperature
- Limited to 475 K
- Separate theta planarization module with ±5° rotation mechanism is provided

Part number	Connector type	Maximum frequency (GHz)	Pitch (µm)
GSG-050-40A-55I-E	K	40	50
GSG-100-40A-55I-E			100
GSG-150-40A-55I-E			150
GSG-200-40A-55I-E			200
GSG-250-40A-55I-E			250
GSG-050-50A-55I-E	2.4 mm	50	50
GSG-100-50A-55I-E			100
GSG-150-50A-55I-E			150
GSG-200-50A-55I-E			200
GSG-250-50A-55I-E			250
GSG-050-67A-55I-E	1.85 mm	67	50
GSG-100-67A-55I-E			100
GSG-150-67A-55I-E			150
GSG-200-67A-55I-E			200
GSG-250-67A-55I-E			250

TABLE 1-11 ***GSG microwave probes***

1.5.5 GSG Microwave Cables

- Loss-less compression seal
- Semirigid with Teflon® dielectric

Part number	Cable type	Feedthrough type	Maximum temperature	Connector type	Maximum frequency
MWC-009-00K	Semirigid microwave coaxial	Loss-less compression seal	475 K	K (SMA compatible)	40 GHz
MWC-009-240				2.4 mm	50 GHz
MWC-009-185				1.85 mm	67 GHz

TABLE 1-12 ***GSG microwave cables***

1.5.6 Sample Holders

Typical sample holder configuration characterized by:

- Leakage resistance between
  - Top surface and guard
  - Guard and ground
- Capacitance between
  - Top surface and guard
  - Guard and ground

Types of sample holders:

- Grounded sample holder—sample mount surface at system ground
- Isolated sample holder—backside contact not needed; sample mount surface is electrically non-conductive and isolated from ground
- Coaxial sample holder—backside contact can be made; sample mount surface is isolated from ground
- Triaxial sample holder—guarded backside contact can be made; sample mount surface has guarded isolation from ground

Part number	Measurement configuration	Separate feedthrough required	Maximum sample (diameter)	Maximum temperature
SH-1.25-G	Grounded	No	Ø32 mm (1.25 in)	475 K
SH-1.25-I	Isolated			400 K
SH-1.25-C	Coaxial	Yes*		
SH-1.25-T	Triaxial	Yes**		
SH-2.00-G	Grounded	No	Ø51 mm (2 in)	475 K
SH-2.00-C	Coaxial	Yes*		400 K
SH-2.00-T	Triaxial	Yes**		

**Coaxial sample holders require one FT-BNC or FT-TRIAX feedthrough as listed below*
***Triaxial sample holders require one FT-TRIAX feedthrough as listed below*

TABLE 1-13 ***Sample holders***

Part number	Description
FT-BNC	Coaxial feedthrough and coaxial cable, installed and wired
FT-TRIAX	Triaxial feedthrough and coaxial cable, installed and wired

TABLE 1-14 ***Feedthroughs***

1.6 Equipment Options

Part number	Description
PS-HV-CPX	High vacuum option. Ensures that condensation does not accumulate in the sample environment during cooldown. This is critical for measuring organic semiconductors and for high Z and low current applications. Includes HVAC port, Varian V301 turbo pump kit, and related HVAC components. Vacuum specifications: radiation shields at room temperature with DUT at maximum sample stage temperature: 10^{-5} Torr; room temperature: 10^{-6} Torr; cold radiation shields with DUT at maximum sample stage temperature: 10^{-6} Torr; cold radiation shields with DUT at room temperature or below: 10^{-7} Torr
PS-LL-CPX	Load-lock assembly option. Allows sample exchange without warming the radiation shields or breaking vacuum, significantly improving efficiency and throughput by reducing cycle time to roughly 1 h. Load-lock also allows samples to be exchanged under controlled environmental conditions. Overall temperature range limited from 10 K to 400 K when using this option.
PS-SSVAC-CPX	Stainless steel vacuum chamber upgrade; supplied in place of standard nickel-plated aluminum vacuum chamber
PS-FOA	Optical fiber assembly. Transmit or receive light or IR/UV radiation. Optical fiber terminated with SMA connector or compression feedthrough. (Optical fiber not included. Optical fiber and probe cannot be used simultaneously.)
PS-Z16	16:1 zoom microscope upgrade; provides 4 µm resolution NOTE: Consult Lake Shore for field upgrade
PS-LT	2.0 K base temperature stage pumping option—includes system modifications, stainless steel flex hose for pump connection, and Varian DS402 rotary pump (12.3 CFM at 60 Hz with oil mist eliminator on output [with oil return], and inlet oil demister)
PS-PLVI-25	Pump-line vibration isolator—includes NW 25 fittings, 1 m stainless steel bellows, clamps, and rings (placed between pump cart and system); requires one bag of cement
PS-V81DP	Turbo pumping system—includes Varian V-81 turbo pump cart with oil free dry scroll backing pump, vacuum gauging for high vacuum and foreline, controller, and adaptors (specify 120 V/60 Hz or 220 V/50 Hz)
PS-PLVI-40	Pump-line vibration isolator—includes NW 40 fittings, 1 m stainless steel bellows, clamps, and rings (placed between pump cart and system); requires one bag of cement
PS-VLT-CPX	1.5 K base temperature assembly—includes adapter, 4 K shield, and Model SH-1.00-G 25 mm (1 in) grounded sample holder NOTE: Must be purchased in addition to PS-LT; maximum sample size limited to 25 mm (1 in) with this option—additional sample holders sold separately; 50 Hz operation may increase base temperature
PS-DPC	Automatic Dewar (gas) pressure controller, regulates Dewar liquid flow
PS-LN2	Nitrogen Dewar with stainless fittings, gauges, and adaptors; allows LN_2 use with the LHe transfer line
PS-PVIS	Pneumatic vibration isolation system—gimbal piston isolator, actuators, and supports (isolator natural frequency: vertical 0.8 Hz, horizontal 1.0 Hz; isolation efficiency at 5 Hz: vertical 80 to 97%, horizontal 60 to 90%; efficiency at 10 Hz: vertical 90 to 99%, horizontal 70 to 95%); requires 40 psi nitrogen or air
PS-OAC	Oil-less compressor for PS-PVIS (only available in 120 V)
PA-SEN	Probe arm modification with temperature sensor installed and wired to a 6-pin feedthrough
PS-PAB-09	Probe arm and base
CS-5	Calibration substrate for GSG probes—pad size: 50 µm²; calibration type: SOLT (short-open-load-through), LRL (line-reflective-line), LRM (line-reflective-match); pitch range: 75 to 250 µm
CS-15	Calibration substrate for GSG probes—pad size: 25 µm²; calibration type: SOLT (short-open-load-through), LRL (line-reflective-line), LRM (line-reflective-match); pitch range: 40 to 150 µm

TABLE 1-15 ***Equipment options***

1.7 Safety Considerations

Observe these general safety precautions and all warning a cautions throughout this manual during all phases of instrument operation, service, and repair. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended instrument use. Lake Shore Cryotronics, Inc. assumes no liability for customer failure to comply with these requirements.

The CPX probe station protects the operator and surrounding area from electric shock or burn, mechanical hazards, excessive temperature, and spread of fire from the instrument. Environmental conditions outside of the conditions below may pose a hazard to the operator and surrounding area.

- Indoor use
- Altitude to 2000 m
- Temperature for safe operation: 5 °C to 40 °C
- Maximum relative humidity: 80% for temperature up to 31 °C decreasing linearly to 50% at 40 °C
- Power supply voltage fluctuations not to exceed ±10% of the nominal voltage.
- Overvoltage category II
- Pollution degree 2

Ground the Instrument
To minimize shock hazard, the instrument is equipped with a three-conductor AC power cable. Plug the power cable into an approved three-contact electrical outlet or use a three-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and mating plug of the power cable meet Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) safety standards.

Ventilation
The instruments have ventilation holes in its side covers. Do not block these holes when the instruments are operating.

Do Not Operate in an Explosive Atmosphere
Do not operate the probe station in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

Do Not Substitute Parts or Modify Instrument
Do not install substitute parts or perform any unauthorized modification to the probe station. Return it to an authorized Lake Shore Cryotronics, Inc. representative for service and repair to ensure that safety features are maintained.

Cleaning
Clean only as directed in section 6.2.

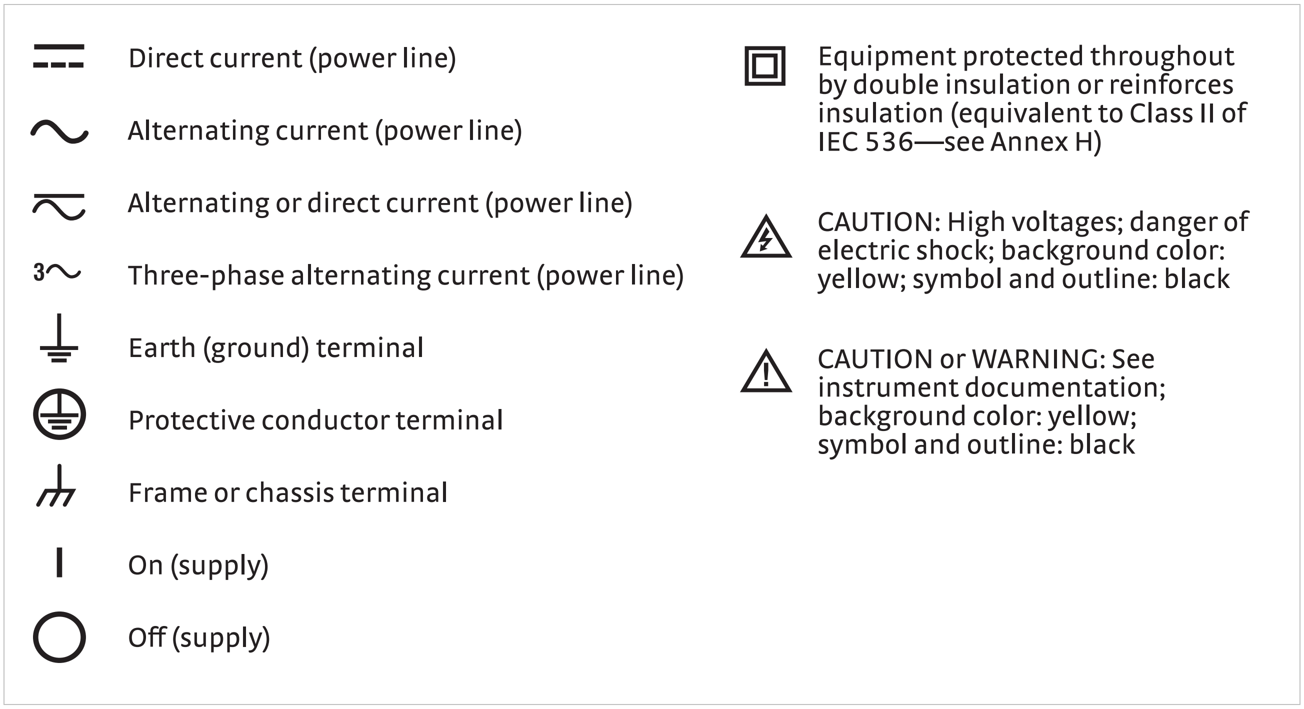


FIGURE 1-1 ***Safety symbols***

Chapter 2: System Overview

2.1 General

Chapter 2 illustrates the major CPX components, options and accessories necessary to provide the features and specifications listed in Chapter 1.

2.2 Major Components

This section is intended as a reference for identifying assemblies, operator interfaces and controls called out in later chapters. A CPX probe station comprises the probe station itself and four major sub-systems. FIGURE 2-1 illustrates an overall view of the full system. Each major component is detailed in the following sections.

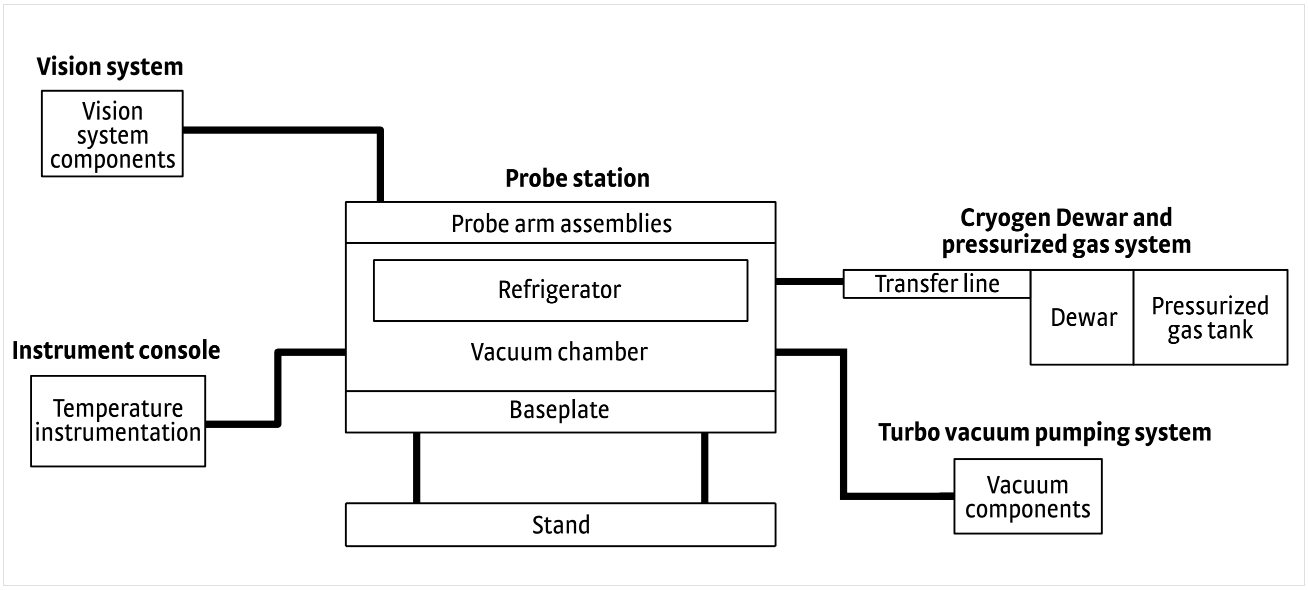


FIGURE 2-1 ***CPX probe station major components***

2.2.1 Probe Station

The probe station provides the temperature measurement environment for the sample or device under test (DUT). It also provides the electrical and optical interface with the sample. Major components of the probe station include the vacuum chamber, refrigerator, and baseplate (the probe station is not mounted to the stand), and probe arm assemblies. FIGURE 2-2 illustrates the probe station components.

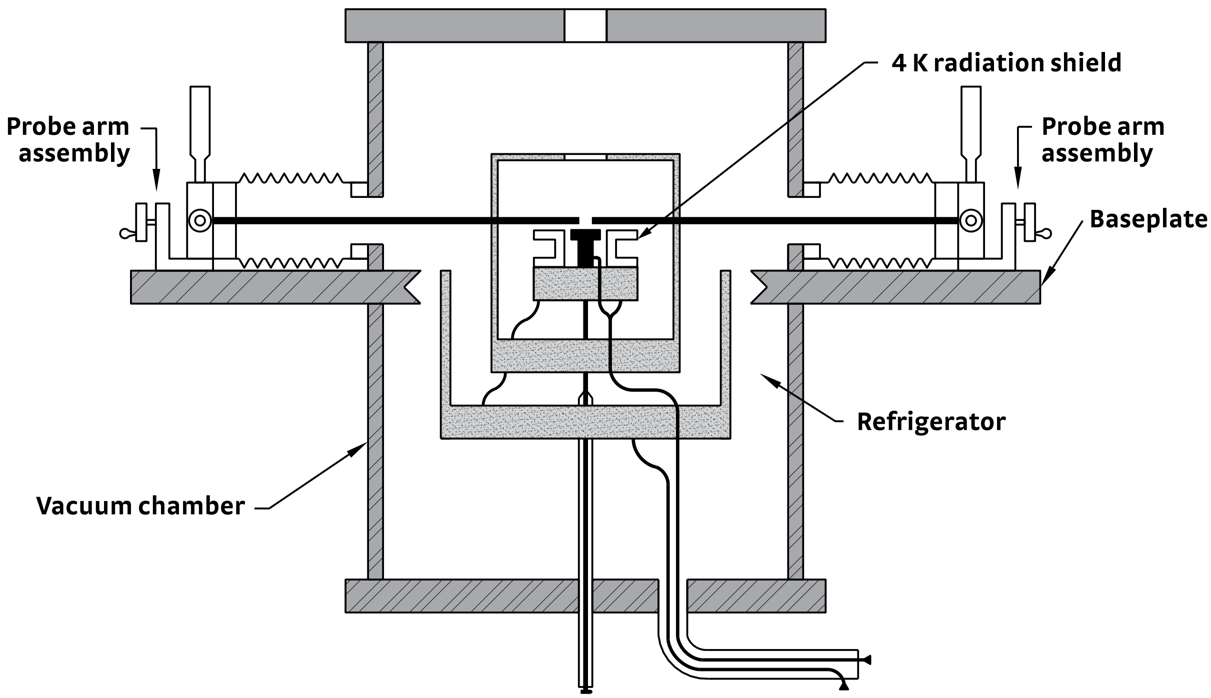


FIGURE 2-2 ***Probe station***

2.2.1.1 Vacuum Chamber

Vacuum is important for two reasons. It provides thermal insulation for the cryogenic refrigeration used to cool the sample and radiation shields, and it also prevents particulates and air in the chamber from condensing on the sample, which may lead to sample contamination during measurements. The vacuum chamber houses both the refrigerator and the radiation shield subsystems. Major components of the vacuum chamber include the vacuum chamber, lid, chamber viewport, vacuum isolation valve, vacuum line, purge valve, pressure relief valve, electrical feedthrough, and auxiliary gauge port. FIGURE 2-3 illustrates the vacuum chamber.

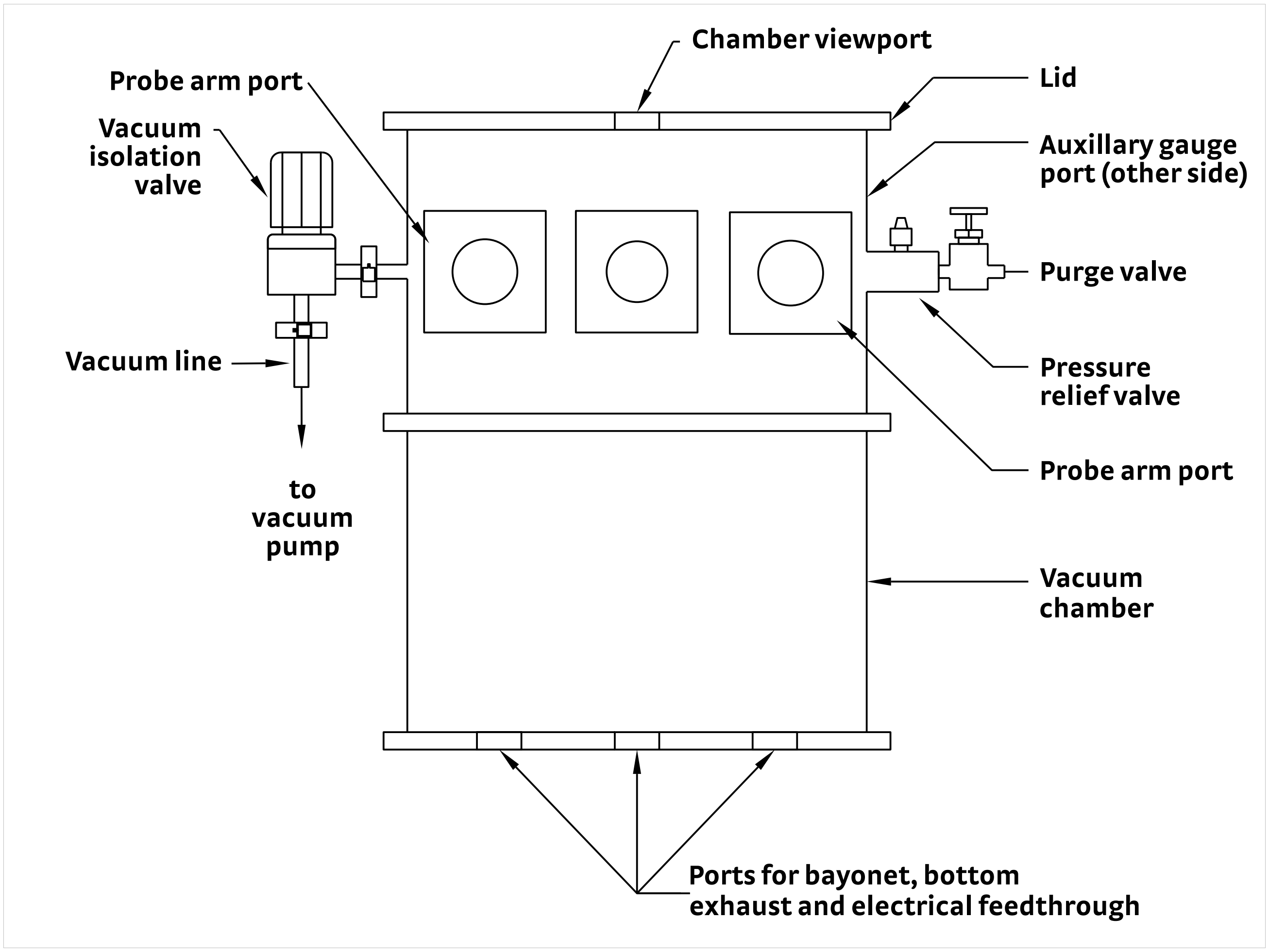


FIGURE 2-3 ***Vacuum chamber***

2.2.1.2 Refrigerator

The CPX uses an open flow cryogenic refrigerator. The refrigerator contains several features to optimize performance and efficiency. One notable feature is that the sample stage and radiation shields have separate flow paths (split flow). This enables the sample stage to be operated above or below the temperature of the 4 K shield stage. Major components of the refrigerator include the sample stage, 4 K radiation shield stage, radiation shield stage, radiation shield, radiation shield viewport, second shield stage, and second shield. A temperature sensor and heater on the sample stage provide a means of sample temperature control. Temperature sensors and heaters on the lower stages allow temperature monitoring and quick warm up to room temperature for sample exchange. FIGURE 2-4 illustrates the refrigerator.

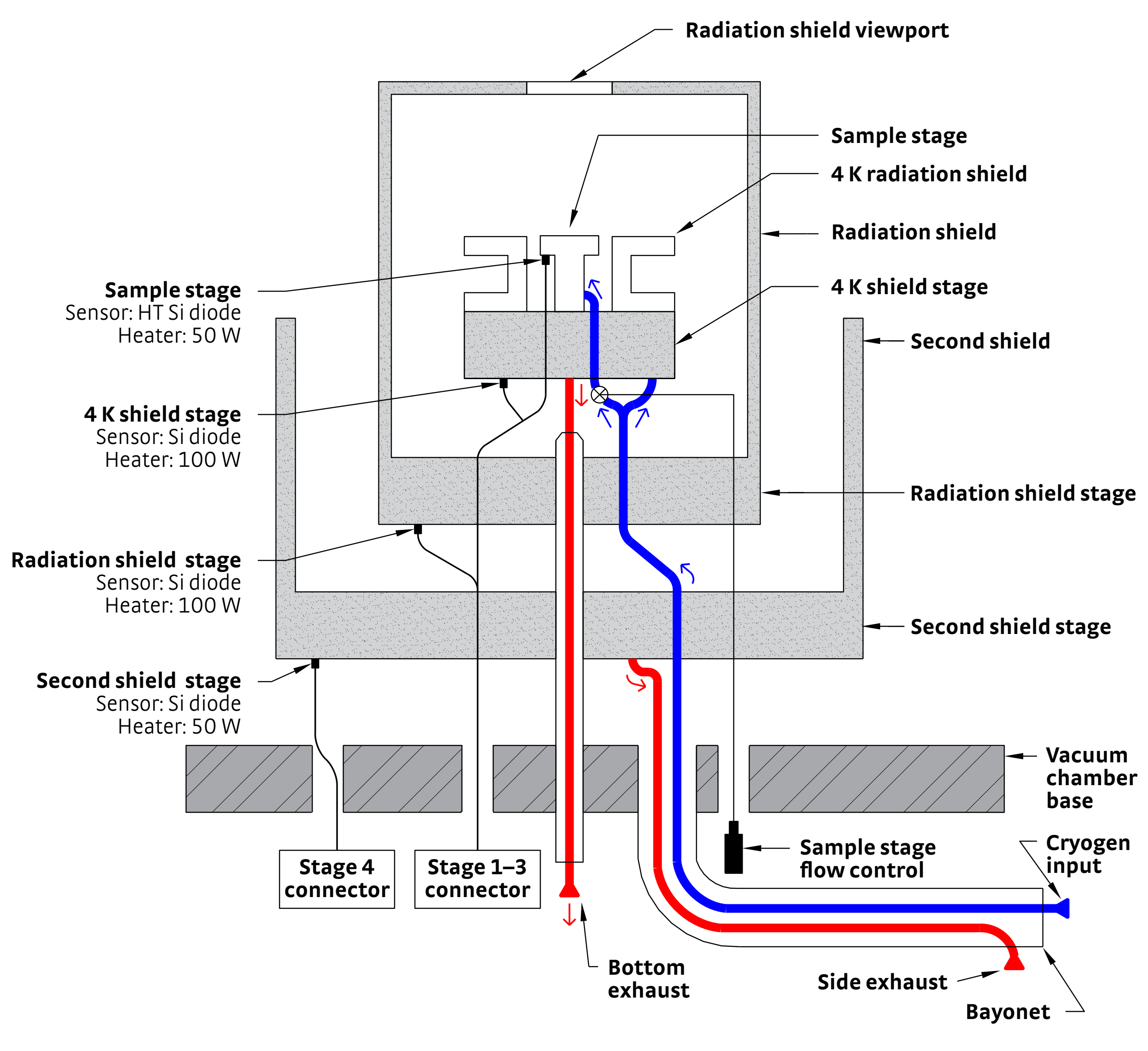


FIGURE 2-4 ***Refrigerator***

2.2.1.3 Micro-manipulated Stages

Up to six micro-manipulated stages can be installed on the CPX. The micro-manipulated stage includes x, y and z micro-manipulated translation stages with micrometer or hand dial controls, probe arm base (top feedthrough for user configurable signal connector), bellows, probe arm, arm shield braids, probe arm sensor (provided on one arm), and optional planarization adjustment (FIGURE 2-5 and FIGURE 2-6).

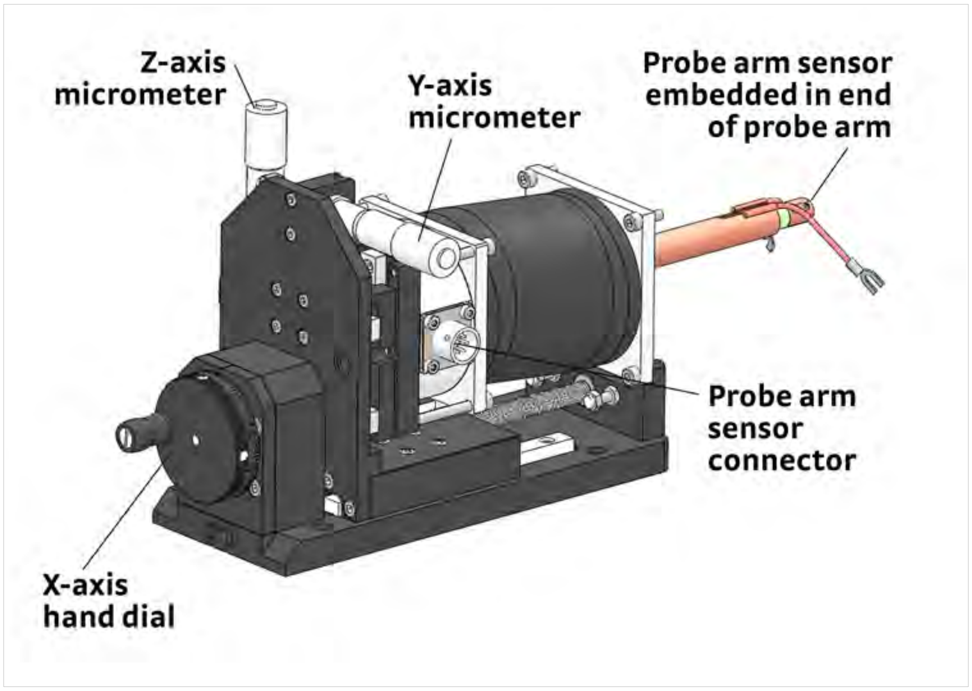


FIGURE 2-5 ***Micro-manipulated stage***

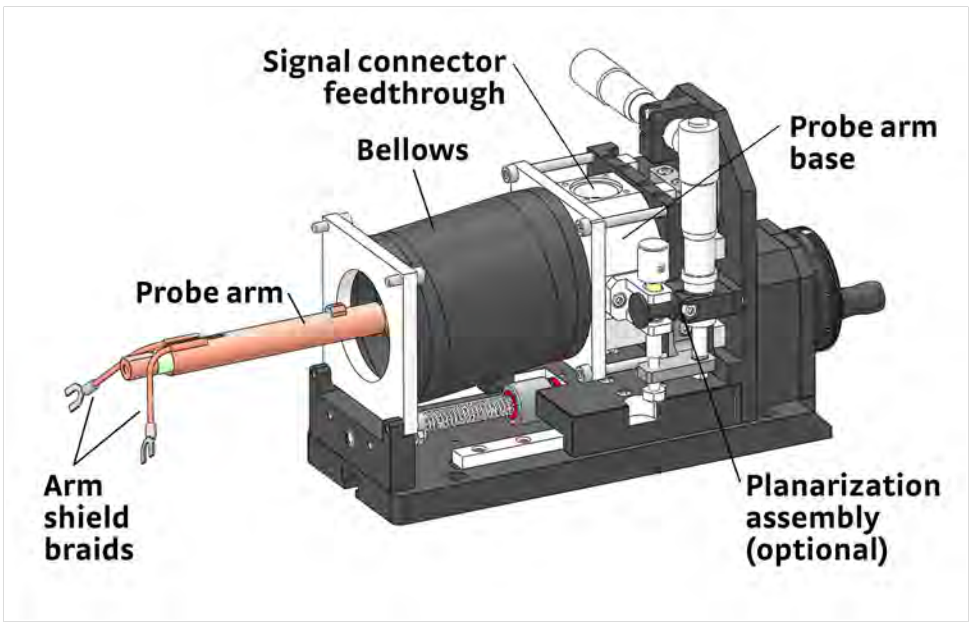


FIGURE 2-6 ***Micro-manipulated stage showing optional planarization assembly***

2.2.2 Cryogen Dewar and Pressurized Gas System

Major components of the cryogen Dewar and pressurized gas system include the Dewar, pressurized gas tank, and transfer line. The cryogen Dewar provides either liquid helium or liquid nitrogen used for cooling the refrigerator of the probe station. The pressurized gas is used to facilitate the transfer of the cryogen to the probe station. FIGURE 2-7 illustrates the system components.

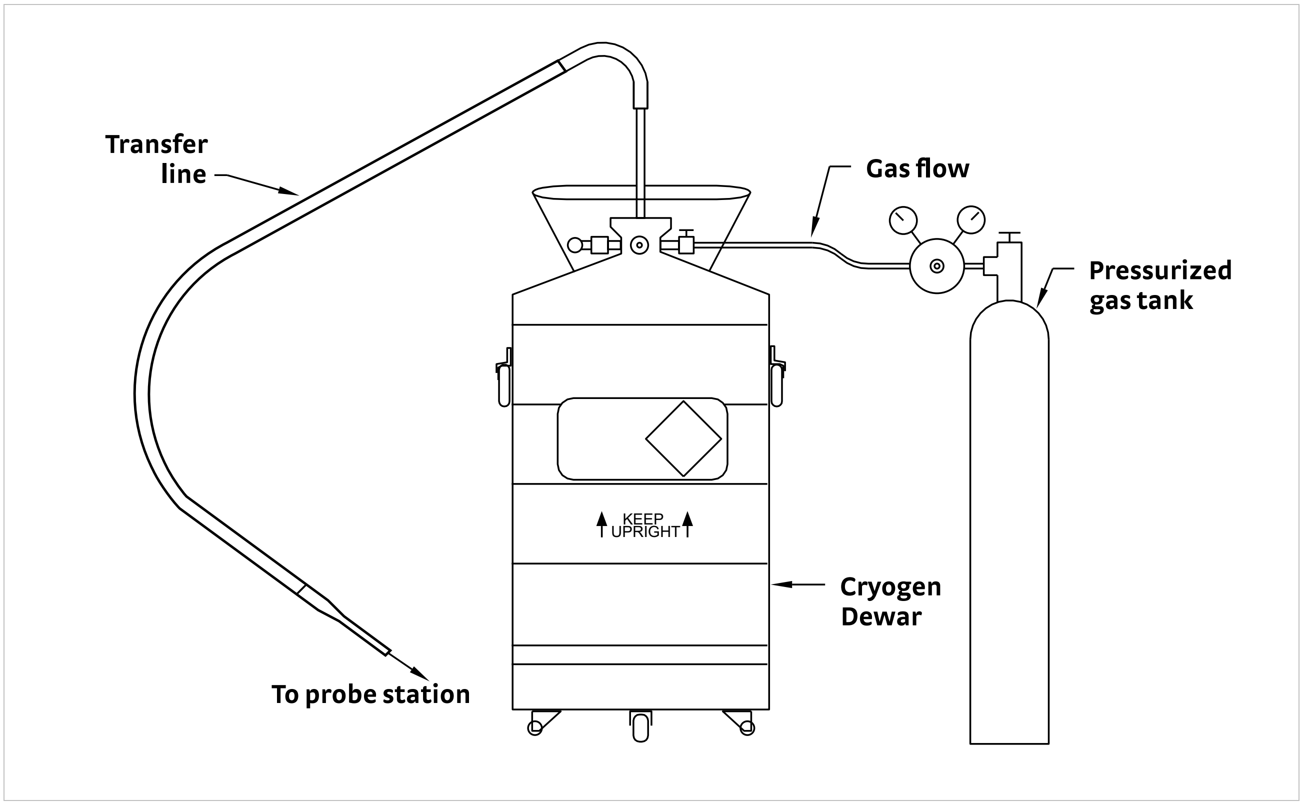


FIGURE 2-7 ***Cryogen Dewar and pressurized gas system***

2.2.2.1 Transfer Line

The vacuum insulated transfer line carries liquid cryogen from the Dewar to the probe station. The supply leg is 12.7 mm (0.5 in) in diameter and incorporates a foot valve and filter at the bottom. The foot valve is used to regulate flow through the transfer line and the filter prevents ice from entering the line. The foot valve control knob is located at the top of the supply side leg so it can be accessed when the line is cold. The target leg is designed to form a gas tight seal when properly inserted into the bayonet on the probe station refrigerator. FIGURE 2-8 illustrates the transfer line.

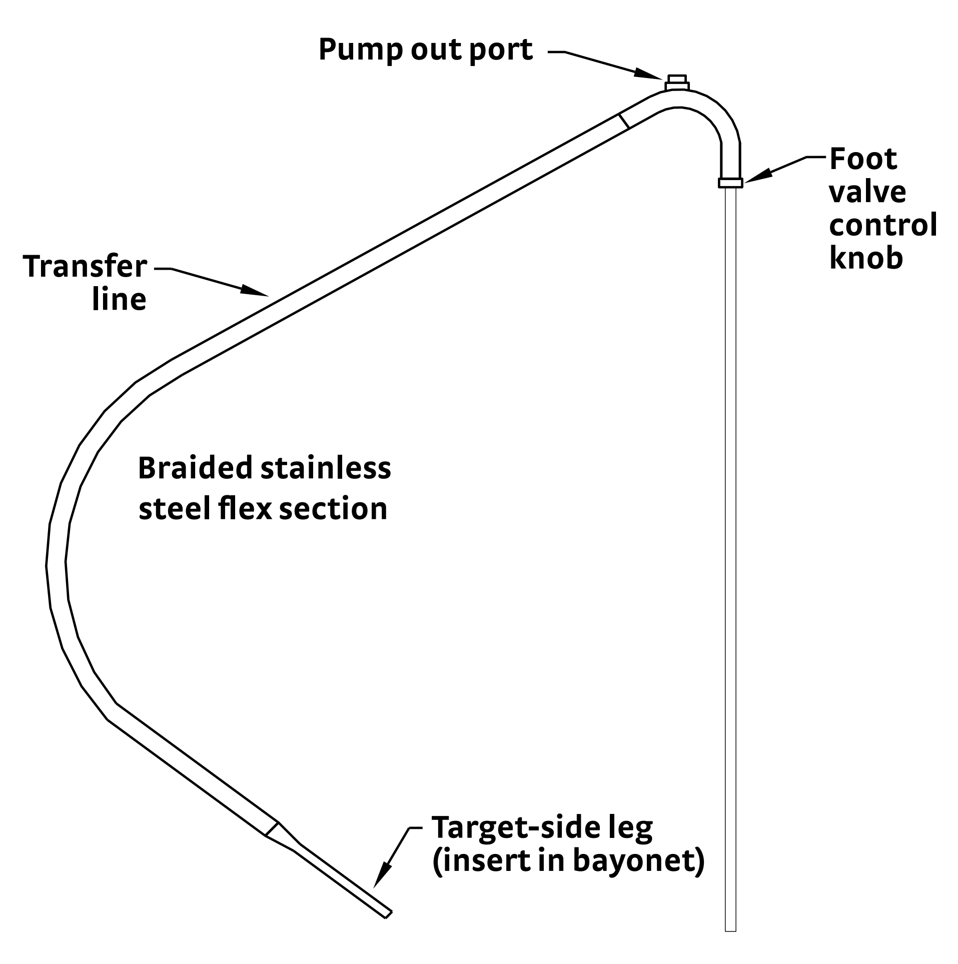


FIGURE 2-8 ***Transfer line***

NOTE

The transfer line is included with the probe station; the following components in sections 2.2.2.2 and 2.2.2.3 are not included with the probe station. They are, however, required for operation of the probe station and must be supplied by the customer

2.2.2.2 Cryogen Dewar

Major features of a typical cryogen Dewar include the Dewar, Dewar pressure gauge, top withdraw port, gas port, gas shut off valve, low pressure relief valve with shut off valve and high pressure relief valve. FIGURE 2-9 illustrates a typical helium Dewar.

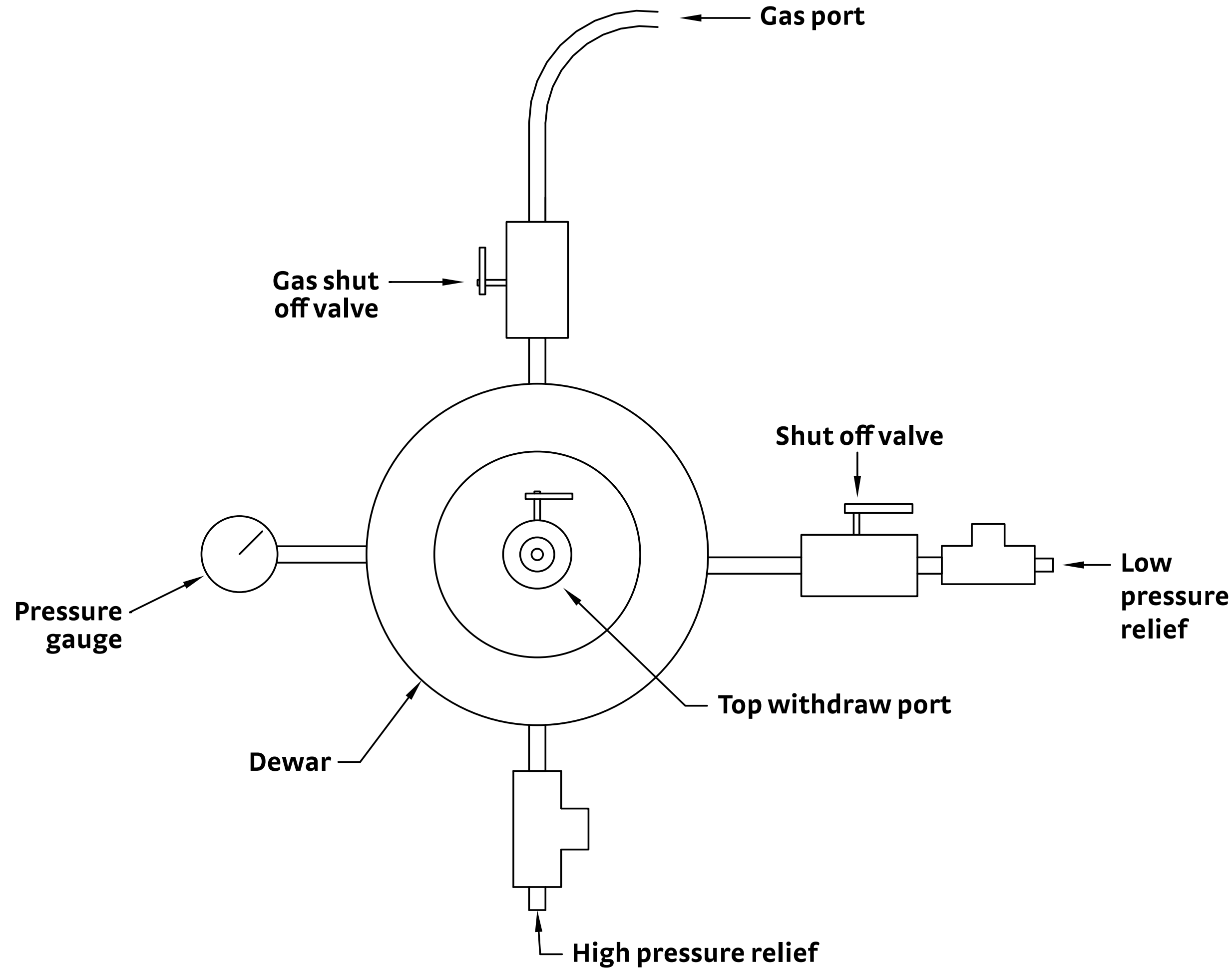


FIGURE 2-9 ***Cryogen Dewar (top view)***

2.2.2.3 Pressurized Gas System

The pressurized gas system typically includes the tank, output pressure regulator, pressure gauges and gas output. FIGURE 2-10 illustrates the pressurized gas system.

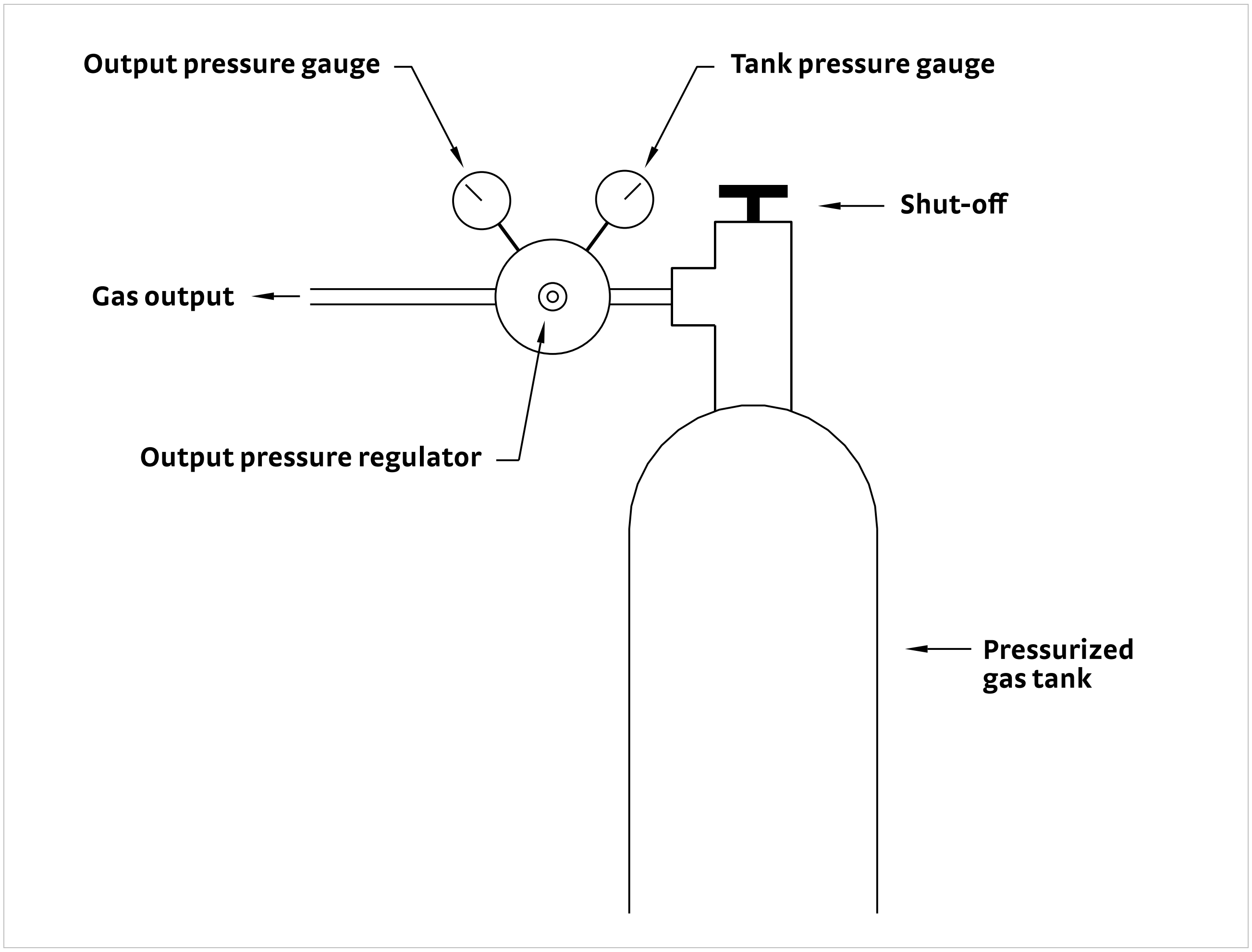


FIGURE 2-10 ***Pressurized gas system (profile)***

2.2.3 Instrument Console

Major instrument console components include the temperature instrumentation and the Model 142 amplifier. FIGURE 2-11 illustrates the instrumentation components.

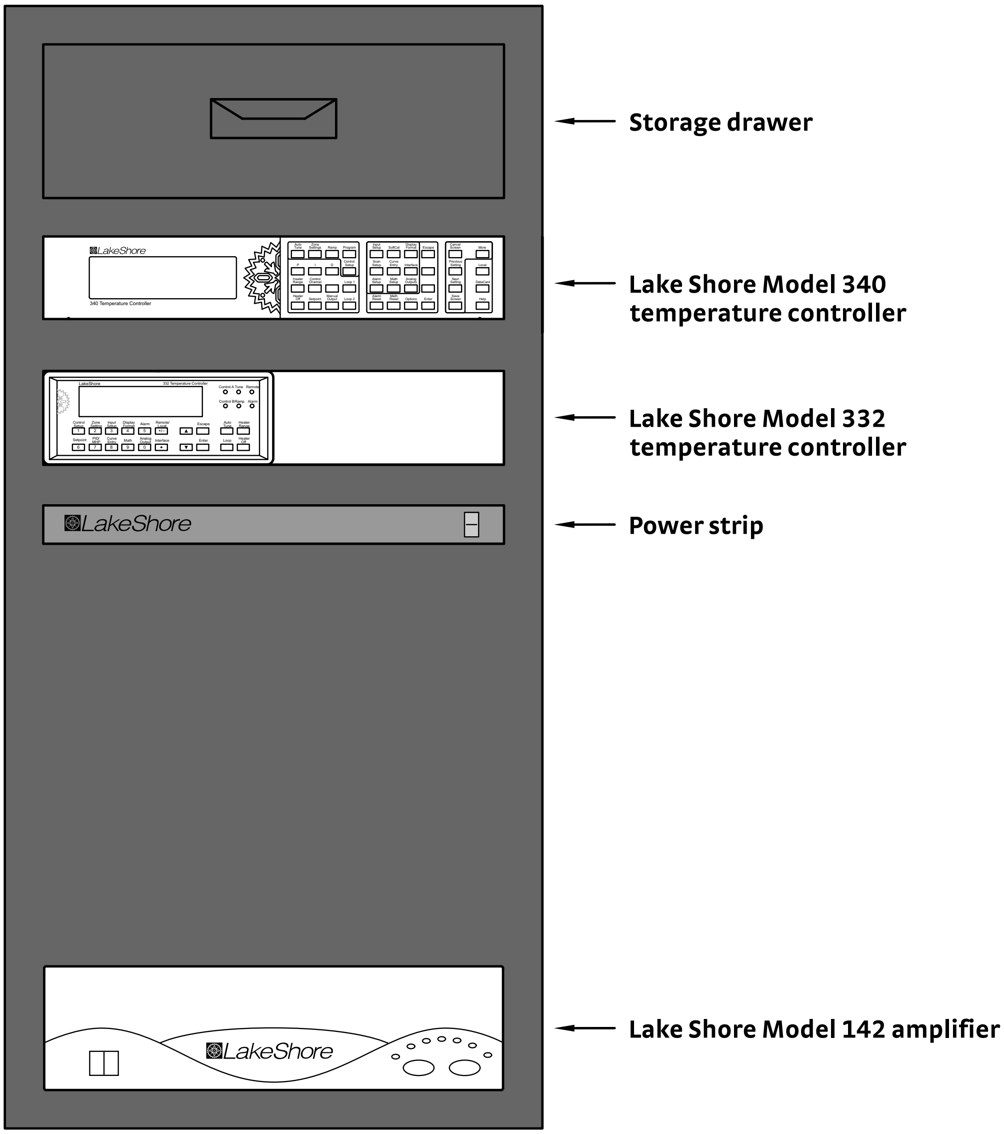


FIGURE 2-11 ***Instrument console***

2.2.3.1 Temperature Instrumentation

The temperature instrumentation includes two Lake Shore temperature controllers: Model 340 and Model 332, and a Model 142 amplifier. The instruments are housed in the instrument console. FIGURE 2-12 illustrates the temperature instrumentation and provides a summary of the probe station component that is monitored or controlled by each controller input.

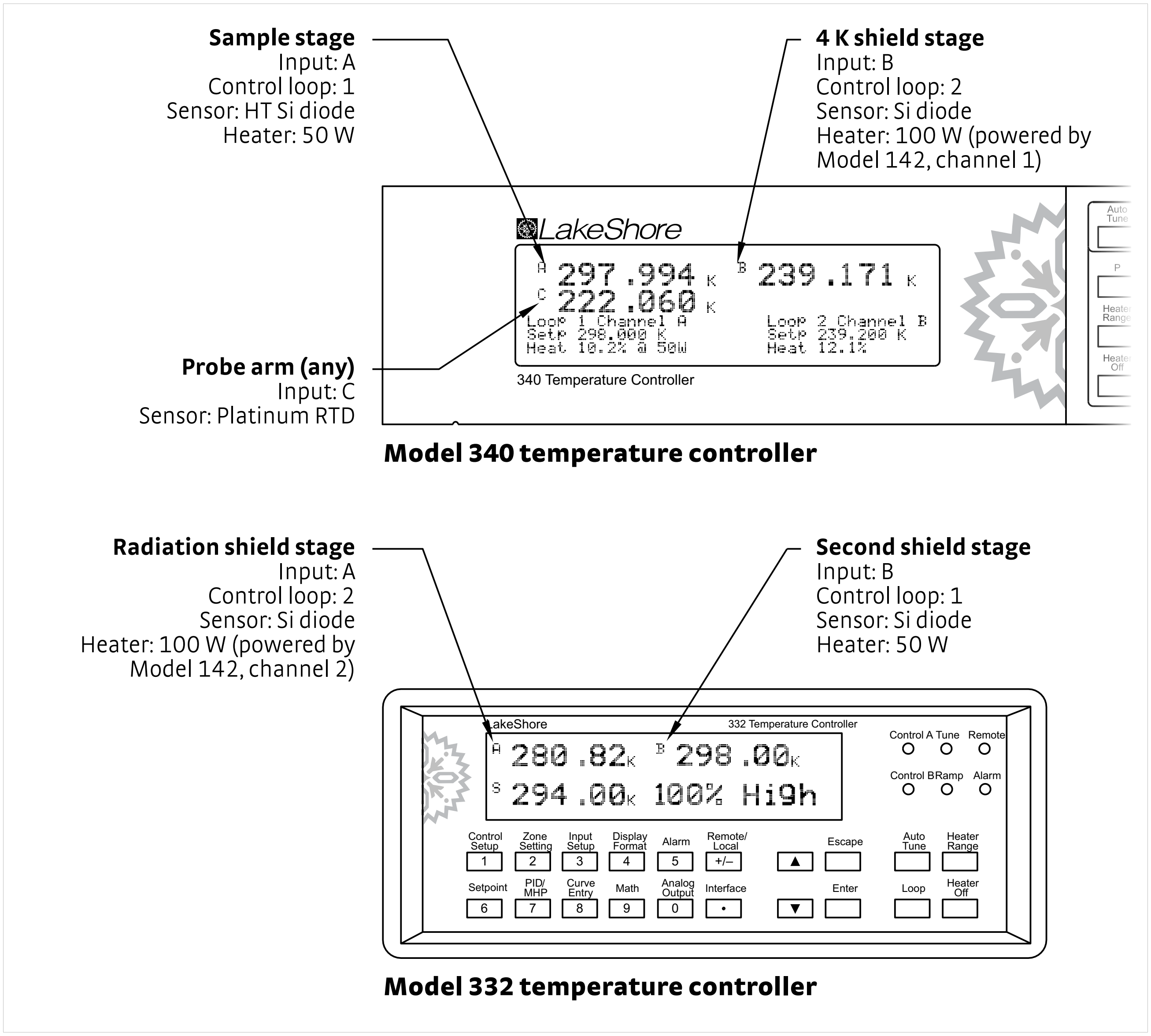


FIGURE 2-12 ***Temperature instrumentation***

2.2.4 Vision System

Major components of the vision system include the microscope, color CCD camera, monitor, support and adjustment apparatus, light, and light source. FIGURE 2-13 illustrates the vision system.

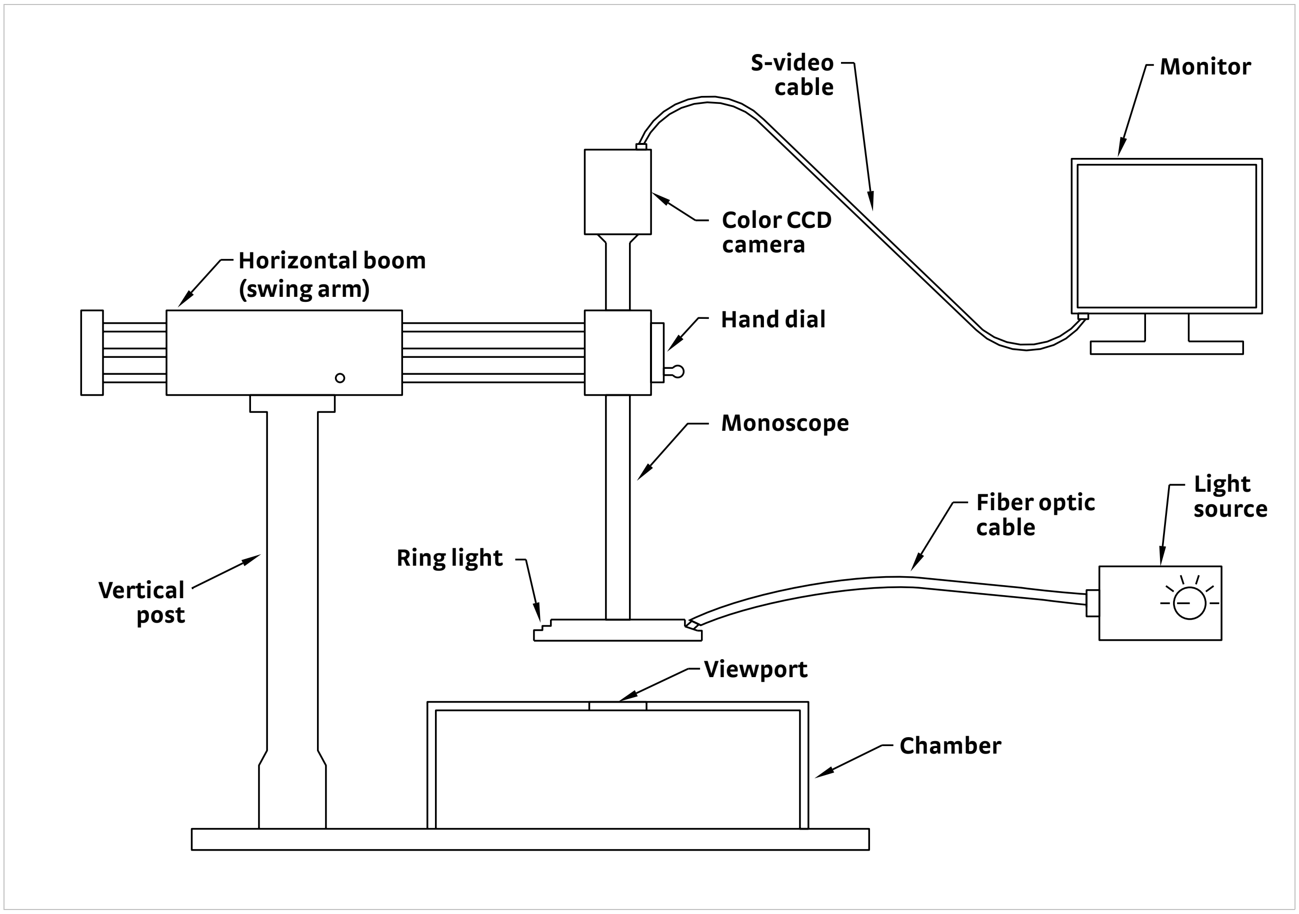


FIGURE 2-13 ***Vision system (with ring light shown)***

2.2.5 Turbo Pumping System (Optional PS-V81DP or Equivalent)

Major components of the turbo pumping system typically include the controller, turbo pump, oil free dry scroll backing pump, vacuum gauge, and vent valve. FIGURE 2-14 illustrates the PS-V81DP turbo pumping system.

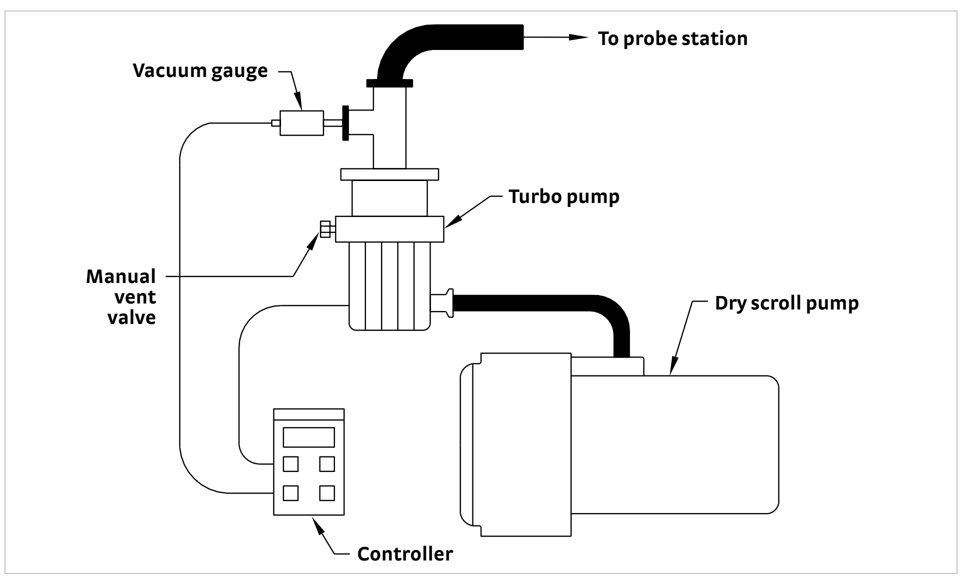


FIGURE 2-14 ***Turbo pumping system***

2.3 Configurations, Options and Accessories

This section illustrates and describes optional components for the probe station. A wide selection of probes, cables, sample holders, and options make it possible to configure the probe station to meet a variety of specific measurement applications.

2.3.1 Probing Configurations

Each of the six probing positions in the CPX can be configured with a user specified arm assembly and probe. Arm assemblies are made up of several components and can be optimized for different probes and measurement techniques. They share the same basic requirements of a micro-manipulated stage, welded stainless steel bellows, probe arm and base, cable and probe mount. The micro-manipulated stages translate the probe in x, y and z axes and are common to all probe configurations.

If the system is not fully populated when ordered, additional arm assemblies can be ordered as MMS-09 options and added in the field. A probe arm and base are included with each assembly whether ordered with the system or separately. Stages ordered with microwave cables will include planarization assemblies. Additional planarization assemblies can be ordered for reconfiguration in the field.

Additional arm and base assemblies will facilitate reconfiguration of the system if different cables are routinely exchanged on the same micro-manipulated stage. The probe arm and base can be ordered as PS-PAB-09 options. Those needing optical fiber assemblies will also need to order PS-FOA options with the probe arm and base.

On typical systems, one arm is provided with a temperature sensor for monitoring nominal arm temperature. Additional sensors are available as PA-SEN temperature sensor options, but must be ordered with the arm and base assembly.

Probing configurations are divided into three basic groups, DC/RF (section 2.3.2), microwave (section 2.3.3) and optical fiber (section 2.3.4).

2.3.2 DC/RF (ZN50) Probe Configurations

DC/RF ZN50 probes are commonly used for electrical probing in the CPX. ZN50 series probes can be used for a wide variety of DC and RF probing measurements, as well as other electrical functions like carrying biasing voltage or excitation current. The probes can be used in the continuous frequency range from DC to 100 MHz and selected frequency bands up to 1 GHz, depending on cable connector selection. See section 2.4.1 and section 2.4.3 for further information on the DC and RF performance of the ZN50 probe.

2.3.2.1 ZN50 Probes

ZN50 series probes consist of a probe mount, ceramic blade with SMA electrical connector, and probe tip. Lake Shore offers a large selection of ZN50 probe blades with different tip materials and point radii (sharpnesses). ZN50 probes all share the same basic frequency response and temperature limits, but they can be limited in operation by the choice of probe cable. All ZN50 blades require a ZN50-55I probe mount for the probe arm. The three probe tip materials are:

1. *Tungsten:* this is the stiffest, hardest, and potentially sharpest probe tip material. Best for probing fine detail or scratching through hard oxide layers to make electrical contact with underlying layers.
2. *Beryllium Copper:* softest and most compliant probe tip material. Makes low resistance contacts to conductive surfaces like gold pads, especially with larger diameter tips.
3. *Paliney 7:* least reactive probe tip material. Least likely to form resistive oxides, especially at elevated temperatures.

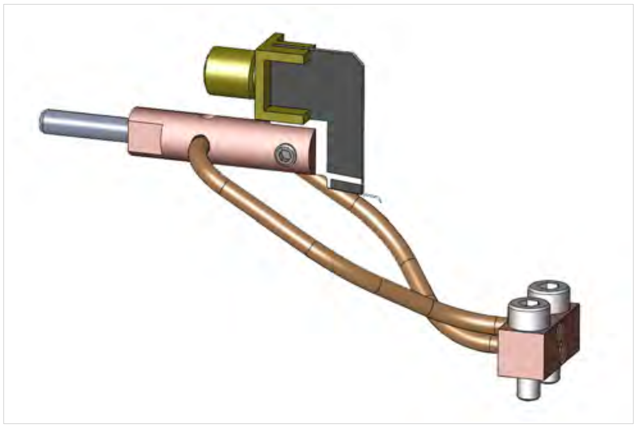


FIGURE 2-15 ***ZN50 probe and mount***

2.3.2.2 ZN50 Compatible Probe Cables and Connectors

ZN50 probe cables with their signal connector and probe connector dominate the electrical characteristics of DC/RF configurations. Each combination has different electrical properties, but they are all compatible with the ZN50 series of probes.

1. *BNC feedthrough with ultra-miniature cryogenic coaxial cable:* is for general purpose DC/RF applications. The BNC signal connector on the probe arm base is easy and economical to interface. Shielding at system ground potential is carried to the probe's ceramic blade. Teflon®-insulated, ultra-miniature cryogenic coaxial cable provides operation up to 50 MHz and 400 K with low thermal conductivity. The probe arm sensor should be monitored when probing a sample above this temperature. SMA probe connectors mate with ZN50 series probes.

2. *Triaxial with ultra-miniature cryogenic coaxial cable:* is for low leakage applications. The triaxial signal connector on the probe arm base permits an active guard to be carried to the probe's ceramic blade. The outermost contact connects electrically to the chamber to provide a shield. The centermost contact is the signal contact, and the contact between the signal and the shield is the guard contact. The connector's signal to guard resistance is specified at >10 GΩ and is typically >50 GΩ when it is clean and dry. The impact of leakage current on measurement uncertainty is further reduced by proper guarding. Teflon®-insulated, ultra-miniature cryogenic coaxial cable provides operation up to 50 MHz and 400 K with low thermal conductivity. The probe arm sensor should be monitored when probing a sample above this temperature. SMA probe connectors mate with ZN50 series probes.

3. *K-connector with semirigid coaxial cable:* is for high frequency applications. The SMA connectors on ZN50 series probes are physically compatible with the K-connectors on 40 GHz microwave cables. This cable configuration enables ZN50 probes to be used continuously up to 100 MHz and at selected bands up to 1 GHz. ZN50 series and 40 GHz microwave probes can be interchanged without rewiring the probe arm. Some limitations apply: a ZN50-55I probe mount is required in the CPX for the ZN50 blades. Semirigid microwave cables are limited to operation below 350 K and are more thermally conductive than ultra-miniature coaxial; therefore, the probe arm sensor should be monitored when probing a sample above this temperature. The cable's outer conductor is grounded to the thermal anchor point of the probe arm shield. See section 2.4.3 for further information on the RF performance of the ZN50 probe.

2.3.2.3 ZN50-Compatible Probe Mount

All ZN50 series blades require a ZN50-55I probe mount that attaches to the probe arm and provides mechanical support and thermal anchoring for the blade. The probe mount braids provide the thermal anchoring and can be connected or disconnected as desired for a particular measurement application. When connected, the probe is maintained at approximately the same temperature as the anchor point. In the CPX, there are two possible probe mount braid anchor points for each probe arm, one on the sample stage and one on the 4 K shield stage.

2.3.3 Microwave Probe Configurations

Matching microwave probes and cables are available in three frequency ranges: DC to 40 GHz, DC to 50 GHz and DC to 67 GHz. Each frequency range uses a different connector type, but all use the same semirigid coaxial cable. Probe arm planarization is necessary to ensure simultaneous contact of all three points of the microwave probe tip. A planarization assembly is included on micro-manipulated stages when microwave cables are ordered, or it can be field installed.

2.3.3.1 Microwave-Compatible Probes

There are three frequency configurations of microwave probes, determined by the connector used. The microwave probe must be specified with the same frequency and connector type as the probe cable. All microwave probes are constructed with ground-signal-ground (GSG) geometry and are designed for use with coplanar waveguides. The BeCu signal and ground points are 10 µm to 12 µm planar triangular structures. The pitch or spacing between the probe points can be specified from 50 µm to 250 µm in 50 µm increments. In general, smaller pitches are recommended for higher frequency applications. The point size is the same regardless of the probe pitch. The probes have a room temperature current limit of 2 A due to heat generated in the probe tip. Consult Lake Shore if this current limit is not sufficient for your application.

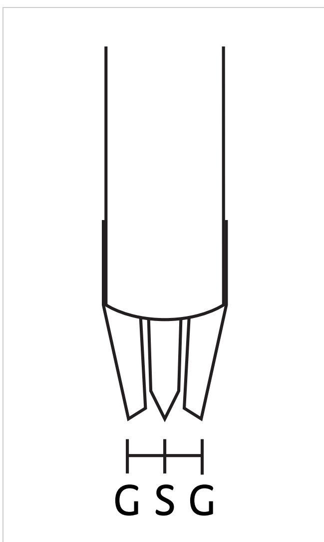


FIGURE 2-16 ***Approximate shape of microwave probe tip.***

Separate probe mounts are not necessary for microwave probes because they are permanently mounted into a proprietary probe body. The proprietary microwave probe body is optimized for thermal performance in cryogenic probe stations and includes both mechanical support and thermal anchoring for the probe.

Microwave probe bodies must be kept below 350 K at all times, but due to the low thermal cross section of the probe points, the probe tips can safely probe substrates that are higher in temperature. With the thermal anchor point for the probes located

on the 4 K shield stage in the CPX probe station, the microwave probes can safely probe a substrate on the sample stage up to 475 K as long as the 4 K shield stage is maintained at 300 K or less. Refer to section 3.5.1 for more discussion on thermal anchoring.

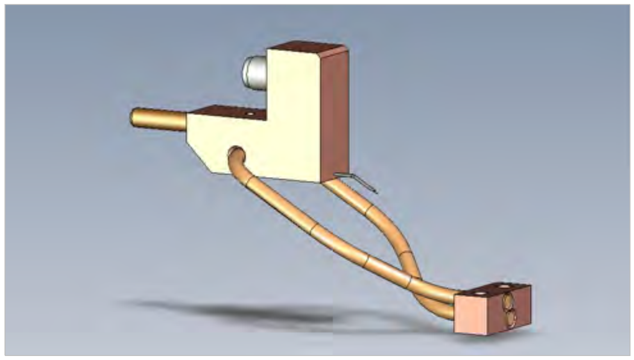


FIGURE 2-17 ***Microwave probe***

2.3.3.2 Microwave-Compatible Cables and Connectors

A microwave probe cable consists of a microwave semirigid coaxial cable with connectors permanently mounted on each end. There are three frequency configurations for the probe cables, determined by the connector used. The cable is fed through the probe arm base with a compression seal to minimize signal loss. The outer conductor of the semirigid coaxial cable is grounded by the thermal anchor of the probe body. The microwave probe must be specified with the same frequency and connector type as the probe cable.

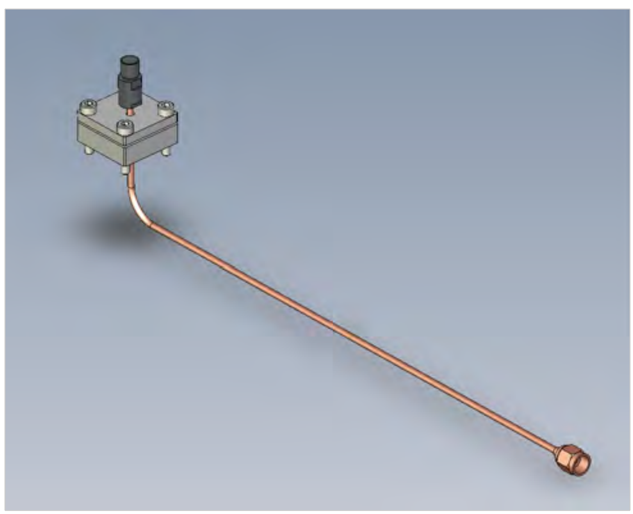


FIGURE 2-18 ***Microwave cable***

Thought should be given to the measurement equipment that will be used with the microwave probes, as the connections on existing measurement equipment may dictate the connectors on the microwave probe arms.

1. *K-connector (2.92 mm) with semirigid cable:* this is the general purpose microwave connection rated for continuous mode free operation from DC to 40 GHz. K-connectors mate to SMA connectors, making this a configuration that allows easy exchange between the microwave probes configured with K-connectors and ZN50 probes that have SMA connectors. This configuration can also be used with external measurement cables with either K-connectors or SMA connectors. The semirigid microwave cable is limited to operation below 350 K.
2. *2.4 mm connector with semirigid cable:* this microwave connection is rated for continuous mode free operation from DC to 50 GHz. 2.4 mm connectors mate to

precision higher frequency V-connectors (1.85 mm). This configuration can be used with external measurement cables with either 2.4 mm or V-connectors. The semirigid microwave cable is limited to operation below 350 K.

3. *V-connector (1.85 mm) with semirigid cable:* this is a precision microwave connection rated for continuous mode free operation from DC to 67 GHz. V-connectors mate to 2.4 mm connectors. This configuration can be used with external measurement cables with either 2.4 mm or V-connectors. The semirigid microwave cable is limited to operation below 350 K.

2.3.3.3 Microwave Calibration Substrate

For the most accurate microwave measurements, especially when performing wide band frequency measurements, the frequency dependent losses in the probes and cables should be removed using a calibration substrate. A calibration substrate is used in conjunction with a vector network analyzer (VNA) to characterize the measurement setup out to the tips of the GSG probe. Lake Shore offers two calibration substrates, CS-5 for 75 µm to 250 µm probe pitch and CS-15 for 50 µm to 150 µm probe pitch. Each substrate is capable of calibrating SOLT (short-open-load-through), LRL (line-reflective-line), and LRM (line-reflective-match). See section 2.5 for more information on microwave calibrations.

FIGURE 2-19 ***CS-5 calibration substrate***

2.3.4 Optical Fiber Assembly

Optical fiber compatible probe arms can be ordered as PS-FOA options. The option is configurable to accommodate a variety of fiber types and applications. Each option includes a probe arm and base with vacuum feedthrough and mount. Lake Shore offers the choice of several optical fibers, or customers can install their own fibers in the field. Contact your Lake Shore sales representative for more information.

2.3.5 Sample Holders

Sample holders attach to the top of the sample stage to provide a good mounting surface for the wafer or device under test. They can be removed easily to facilitate careful sample mounting. One grounded sample holder is included with the system, but it can be interchanged with any of the optional sample holders (as long as the appropriate feedthrough wiring option is installed for coaxial/triaxial). It is often desirable to order more than one holder so one sample can be mounted while another is being measured.

Different models are optimized for different electrical measurement applications. All of the holders are thermally conductive so the sample temperature remains close to the sample stage temperature, but there are some trade-offs between thermal conductivity and electrical characteristics. TABLE 2-1 shows the temperature gradients that are typical between the sample stage temperature sensor and the top of each sample holder. The gradients are given for base temperature, which is the worst case; gradients are smaller at higher temperatures.

Sample holder type	Sample holder model	Maximum sample size	Temperature difference at 4.2 K*	Maximum temperature
Grounded	SH-1.25-G	32 mm (1.25 in)	0.1 K to 0.2 K	475 K
Isolated	SH-1.25-I	32 mm (1.25 in)	~1 K	400 K
Coaxial	SH-1.25-C	32 mm (1.25 in)	~1 K	400 K
Triaxial	SH-1.25-T	32 mm (1.25 in)	~1 K to 2 K	400 K
Grounded	SH-2.00-G	51 mm (2 in)	0.1 K to 0.2 K	475 K
Coaxial	SH-2.00-C	51 mm (2 in)	~1 K	400 K
Triaxial	SH-2.00-T	51 mm (2 in)	~1 K to 2 K	400 K

**Temperature difference between the top of the sample holder and the sample stage temperature sensor. Additional temperature difference can be expected between the sample and sample holder, depending on mounting technique and experimental heat load.*

TABLE 2-1 ***Sample holder summary***

2.3.5.1 Grounded Sample Holders

Grounded holders are the most common type and are referred to as grounded because the back side of the sample is held at system ground. They are recommended for routine measurements, especially when samples are patterned on highly insulating substrates or leakage current is not a concern. They are constructed out of solid metal, making them the most thermally and electrically conductive. The smallest thermal gradient between the sample stage and sample mounting surface can be achieved with the standard SH-1.25-G grounded sample holder. The maximum operating temperature is 475 K when using the grounded sample holder.

2.3.5.2 Isolated Sample Holders

Isolated holders have a nonconductive sample mounting surface that electrically isolates the sample from system ground. They are recommended for measuring samples with electrically conductive features on the back side. They are constructed similarly to grounded holders, but have a sapphire disk attached to the top surface. The sapphire is an excellent electrical insulator and retains good thermal conductivity at cryogenic temperatures. Moderate thermal gradients between the sample stage and sample mounting surface should be expected. The maximum operating temperature is 400 K.

2.3.5.3 Coaxial Sample Holders

Coaxial holders offer the ability to define the voltage potential on the conductive sample mounting surface in addition to isolating it from system ground. They are useful when it is desired to maintain the back side of a substrate at a potential other than chassis ground. They are recommended for applications such as guarding the sample to reduce leakage current, bringing a bias voltage to the back side of the sample or isolating and shielding the sample to reduce noise.

Coaxial holders are constructed as laminations of metal/insulator/metal in the sample plane. The insulator provides a layer to layer resistance of >30 GΩ and a layer to layer capacitance of <150 pF. The conductive sample surface has a contact pin that can be driven at a user defined potential. Wiring for the sample holder requires an FT-BNC or FT-TRIAX feedthrough option. Moderate thermal gradients between the sample stage and sample mounting surface should be expected. The maximum operating temperature is 400 K.

2.3.5.4 Triaxial Sample Holder

Triaxial holders offer the ability to define two different voltage potentials between the conductive sample mounting surface and system ground. They are recommended when two of the features supported by the coaxial sample holder are used at the same time. Examples include guarding to reduce leakage current and shielding to reduce noise or voltage biasing and guarding at the same time.

Triaxial holders are constructed as laminations of metal/insulator/metal/insulator/metal. The insulator provides a layer to layer resistance of >30 GΩ and a layer to layer capacitance of <150 pF. The conductive sample surface and center metal plane both have contact pins that can be driven at user defined potentials. Wiring for these signals requires an FT-TRIAX feedthrough option. Moderate to medium thermal gradients between the sample stage and sample mounting surface should be expected. The maximum operating temperature is 400 K.

2.3.6 Vision System Configuration

The probe station’s vision system is critical for distinguishing characteristics of the sample and properly landing probes. The vision system can be optimized for the type of sample that is most frequently probed. There are four configurations available for the probe station, two different microscopes each with two lighting choices. The choice of an appropriate lighting type is especially important because it strongly influences the behavior of the vision system.

2.3.6.1 Microscopes

There are two microscopes available for the probe station, the standard Zoom 70 and the optional Zoom 160. The Zoom 70 has a ratio of magnification change (zoom) of 7:1 and the Zoom 160 has a ratio of magnification change (zoom) of 16:1. The maximum magnification of the vision system is different than the magnification ratio. Vision system magnification is dependant on the microscope magnification and other factors such as the camera, monitor size and the optical elements necessary to overcome the probe station’s relatively large working distance. Resolution is often a more useful specification than magnification when choosing a microscope.

Lake Shore specifies resolution for the two different microscopes in Chapter 1. The specified resolution indicates the smallest feature that can be reasonably distinguished on the sample’s surface. (The sample’s texture and contrast also affect resolution.) Although the Zoom 160 always offers a higher magnification than the Zoom 70, the useable resolution of the two microscopes is often similar. This is primarily a result of the relatively large working distance between the microscope and sample, which limits the resolution of the Zoom 160. FIGURE 2-20 compares the resolution of the two microscopes under similar conditions in a TTPX probe station. Although the Zoom 160 image has visibly more resolution in this comparison, it is

important to note that these results are difficult to duplicate during actual measurements. Factors such as the sample surface texture and normal levels of room vibration can quickly degrade the resolution of the Zoom 160 to match that of the Zoom 70.

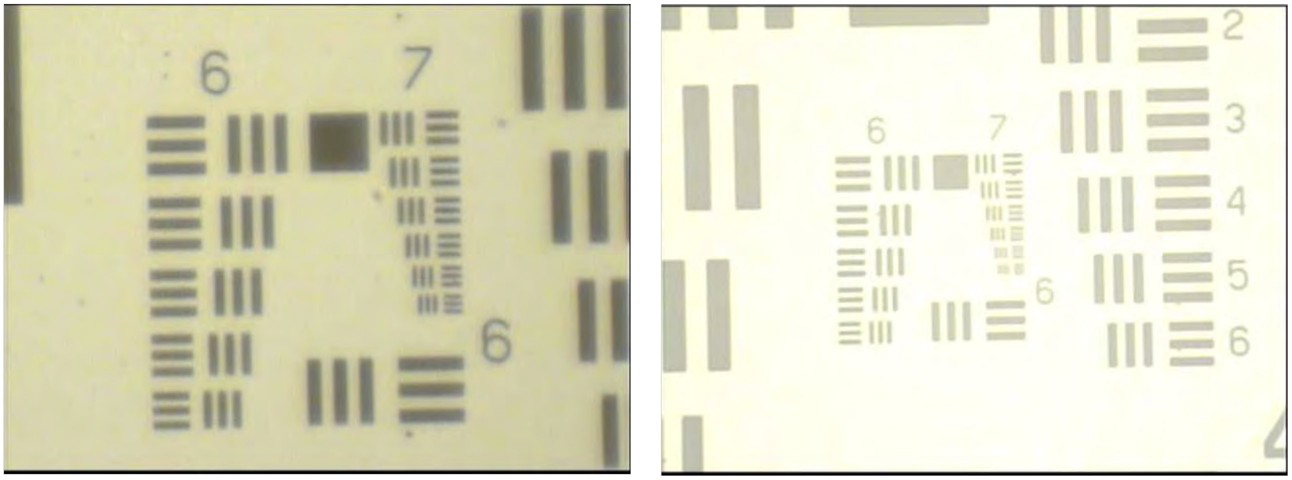


FIGURE 2-20 ***Left: Best case resolution (approximately 2 μm) obtained obtained with Zoom 160 and coaxial light on a TTPX probe station; Right: Typical resolution (approximately 3 μm) obtained with Zoom 70 and coaxial light on a TTPX probe station***

2.3.6.2 Lighting Types

There are two types of lights available for each microscope, coaxial and ring. The primary difference between the two is in the way light is reflected off of the sample surface into the microscope.

The coaxial light configuration guides light from the light source along the same path (coaxially) with the light returning from the sample. This allows the vision system to image very highly reflective samples such as those patterned on polished silicon. FIGURE 2-21 (left) is an image of four gold circles (10 μm to 100 μm in diameter) patterned on a highly reflective surface illuminated with a coaxial light. Although the image appears relatively flat and has modest contrast, it is more than adequate for properly landing probes. FIGURE 2-21 (right) is an image of the same sample illuminated with a ring light. The image is darker and even lower in contrast because nearly all of the light is cleanly reflected away from the microscope. It would be difficult to properly land a probe using this image.

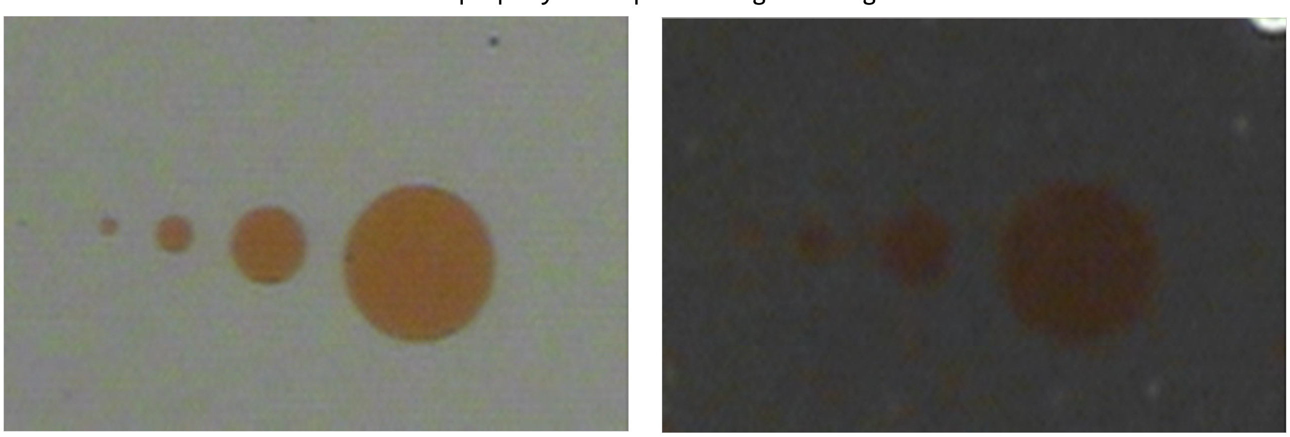
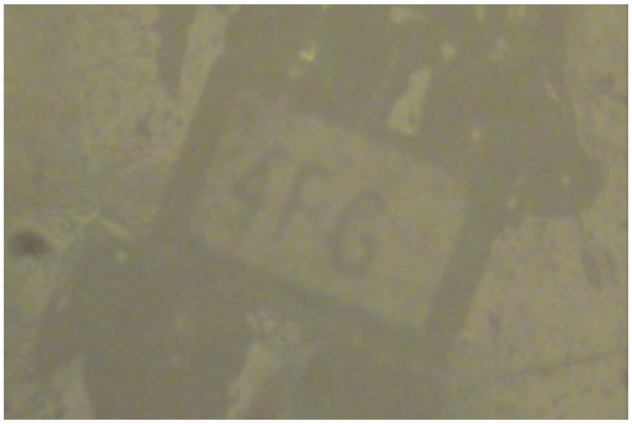


FIGURE 2-21 ***Left: Highly reflective surface through a Zoom 70 with a coaxial light; Right: Highly reflective surface through a Zoom 70 with a ring light***

The ring light surrounds the end of the microscope with light from the source which illuminates the sample from all directions. The light scatters as it reflects off of textured or uneven surfaces, giving images contrast and the appearance of a third dimension. FIGURE 2-22 (right) is an image of a surface mount device illuminated with a ring light. The natural appearance of the sample is preferred by many operators. FIGURE 2-22 (left) is an image of the same device illuminated with a coaxial light. Its flat, two dimensional appearance and low contrast result from all of the light coming from the axis of the microscope. It would be difficult to properly land a probe using this image.



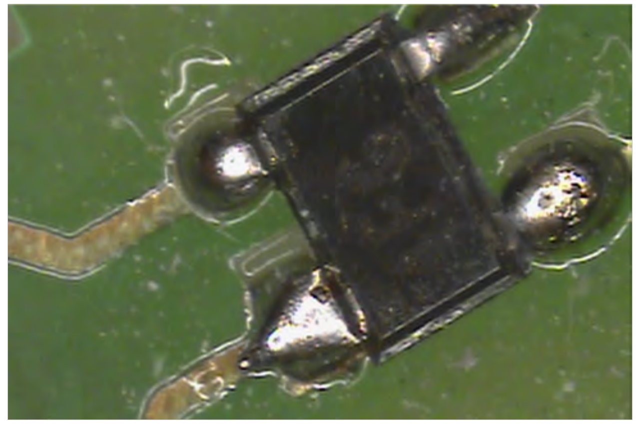


FIGURE 2-22 ***Left: Uneven surface through a Zoom 70 with a coaxial light; Right: Uneven surface through a Zoom 70 with a ring light***

2.3.7 Turbo Pumping System (PS-V81DP)

A turbo pumping system is required to properly evacuate the probe station's vacuum chamber. Chamber vacuum $<10^{-3}$ Torr at room temperature is required for the CPX to operate within specifications. Lake Shore offers turbo pumping systems as the PS-V81DP option for the CPX. The components and specifications for these pumping stations are listed in TABLE 2-2.

Pumping systems can also be sourced locally. Turbo pumps with similar base pressure and pumping speed to those listed in TABLE 2-2 are recommended. A vacuum line and fittings to adapt the pump system to the CPX probe station's NW 40 vacuum isolation valve must also be provided. Lake Shore recommends using a turbo pump controller with safety interlocks to improve usability of the probe station and prevent accidental damage to the probe station and pump.

Turbo pump		Model and type	Varian V81-T turbo pump and controller
		Base pressure	4×10^{-9} Torr (blanked off specification), 10^{-7} Torr (typical in a PS-V81DP configuration)
		Pumping speed	50 L/s (NW 40 flange)
Fore pump		Model and type	Varian SH-110 dry scroll pump
		Pumping speed	110 L/min
		Base pressure	5×10^{-2} Torr
Chamber gauge		Model	Varian EyeSys
		Type	Vacuum gauge
		Range	10^{-2} to 10^{-8} Torr
Gauge readout		Model	Integrated
		Capacity	One-vacuum gauge
General		Size	46 cm (18 in) w × 56 cm (21 in) d × 64 cm (25 in) h
		Weight	22 kg (48.5 lb)
		Power	100/120 V or 220/230/240 V
Included accessories	Vacuum line	Size	NW 40
		Length	1 m (for specified system performance)
		Type	Flexible stainless steel
	Clamps	Size	NW 40

TABLE 2-2 ***PS-V81DP option components***

2.3.8 High Vacuum Option (PS-HV-CPX)

The high vacuum option ensures that condensation does not accumulate in the sample environment during cooldown. This is critical for measuring organic semiconductors and for high Z and low current applications. The high vacuum option includes an HVAC port, Varian V301 turbo pump kit and related HVAC components. The option increases vacuum to as low as 10^{-7} torr.

2.3.9 2 K Base Temperature Option (PS-LT)

The nominal base temperature for the sample stage on a standard CPX is at the boiling point of helium, which is approximately 4.2 K under normal atmospheric conditions. Lower temperatures can be achieved on the sample stage if pressure on the helium in the sample stage is dropped below atmospheric pressure, reducing the boiling point of the helium.

Lake Shore offers the PS-LT option, which can reduce the temperature of the CPX sample stage to 2 K. The option contains everything necessary to establish and regulate temperatures between approximately 2 K and 4.2 K. The main component to the PS-LT option is a Varian DS 402 rotary vacuum pump (or equivalent), which is used to pump on the sample stage exhaust port. A flexible stainless steel vacuum line (bellows) and necessary fittings are included to safely connect the vacuum pump to the probe station. The option also includes a set of cryogenic compatible valves in a dual valve assembly that can be used to regulate temperature.

The PS-LT option can be ordered with the probe station or added later because it does not require changes to the internal refrigerator. The option can be easily removed for standard operation within minutes.

NOTE **Electronic temperature controllers are not capable of controlling sample stage temperature when using the PS-LT option. The included dual valve assembly is required to regulate temperature between 2 K and 4.2 K.**

2.3.10 Load-lock Assembly Option

The load-lock assembly option allows for sample exchange without warming the radiation shields or breaking vacuum, significantly improving efficiency and throughput by reducing cycle time to roughly 1 h. Load-lock also allows samples to be exhanged under controlled environmental conditions. The overall temperature range is limited from 10 K to 400 K when using this option.

The load-lock option includes an electrically isolated adapter for the sample stage, slide-on sample holders, a modified 4 K shield, and a modified radiation shield that provides easy load-lock access.

2.3.11 Liquid Nitrogen Dewar (PS-LN2)

Lake Shore offers a 50 L liquid nitrogen laboratory (storage) Dewar as the PS-LN2 option. The Dewar has a 12.7 mm (0.5 in) top withdraw port that is compatible with the probe station transfer line. Constructed of durable stainless steel, the Dewar includes a pressure gauge, gas port, gas valve and 68.9 kPA (10 psi) pressure relief valve for safe and convenient operation. Dry nitrogen gas is required to pressurize the Dewar during cryogen transfer. The option does not include a nitrogen fill line, gas pressure regulator, gas lines or fittings.

NOTE

Liquid nitrogen will only cool the refrigerator down to 78 K.

2.3.12 Automatic Dewar Pressure Controller (PS-DPC)

The PS-DPC automatic Dewar pressure controller provides a digital readout and digital regulation of the pressure in a helium or nitrogen Dewar. It regulates over the normal operating range of the probe station from approximately 3.4 kPA (0.5 psi) to 68.9 kPA (10 psi). The digital pressure setpoint ensures fast repeatable Dewar pressure settings. The controller connects between the regulated gas source and Dewar, and it is powered by a 9 V battery or the included wall plug power supply.

2.3.13 Pneumatic Vibration Isolation Option (PS-PVIS)

The PS-PVIS option is available for vibration sensitive applications. The flow cryostat in the probe station produces very little vibration, typically <1 µm; therefore, vibration is not a problem for all users. The additional isolation is recommended when probing extremely fine detail, when making measurements that are very sensitive to electrical noise, or when there are likely to be outside vibration sources near the probe station.

The option adds active pneumatic vibration isolation to the CPX's integrated stand. Typical performance and general specifications are given in FIGURE 2-23 and TABLE 2-3. The stand requires a regulated source of compressed air or nitrogen to operate. The PS-OAC oil-less air compressor option is available for use with the PS-PVIS (110 V operation only).

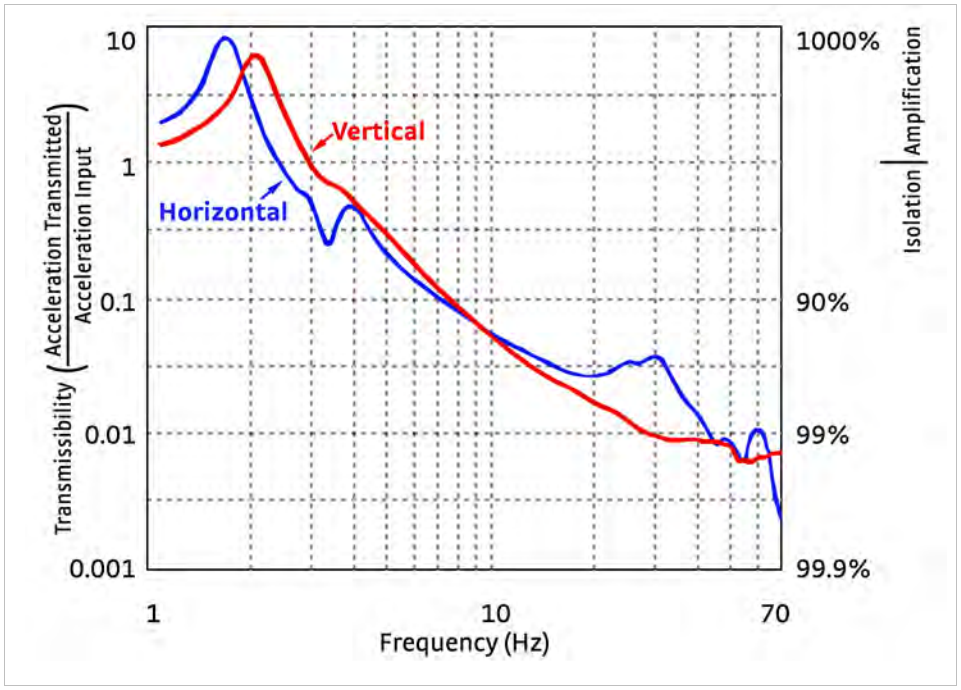


FIGURE 2-23 ***Vibration isolation performance for the TMC stand with option PS-PVIS pneumatic vibration isolation system***
Copyright Technical Manufacturing Corporation. Used with permission.

Isolator natural frequency	High input—vertical	1.2 Hz
	High input—horizontal	1.0 Hz
	Low input—vertical	1.5 Hz to 2.0 Hz
	Low input—horizontal	1.2 Hz to 1.7 Hz
Isolation efficiency at 5 Hz	Vertical	70% to 85%
	Horizontal	75% to 90%
Isolation efficiency at 10 Hz	Vertical	90% to 97%
	Horizontal	90% to 97%
Additional details	Gross load capacity	640 kg (1400 lb)
	Net load capacity	160 kg (350 lb)
	Finish	Medium texture black powder coat
	Facilities required	552 kPa (80 psi*) nitrogen or air

**40 psi required for CPX*

TABLE 2-3 ***Specifications for the TMC stand***
Copyright Technical Manufacturing Corporation. Used with permission.

2.3.14 Pump Line Vibration Isolator (PS-PLVI-40 or 25)

Vacuum pumps are a common source of vibration that can impact sensitive measurements. There are two pumps commonly associated with the probe station, the turbo pumping system used to evacuate the chamber and the 2 K base temperature option pump. A pump line vibration isolator can minimize the vibration from either of these pumps.

When operating at cryogenic temperatures <77 K, the cryopumping action of the refrigerator will maintain sufficient vacuum in the chamber so that the evacuation valve can be closed and the turbo pump turned off. When operating the refrigerator at elevated temperatures, however, the vacuum pump needs to be left connected and operating so vibration isolation is recommended. The PS-PLVI-40 pump line vibration isolator is recommended for isolating the turbo pump for this application. It includes a bucket with NW 40 fittings, a 1 m flexible stainless steel vacuum line and clamps.

A vibration isolator is also recommended any time the PS-LT base temperature option is used with the CPX because the pump must be left running during operation. The PS-PLVI-25 pump line vibration isolator includes a bucket with NW 25 fittings, a 1 m flexible stainless steel vacuum line and clamps.

2.4 Considerations for DC/RF Electrical Measurements

Nearly every DC or RF measurement done in a CPX has some unique configuration or requirement. Although it is impossible to predict every application, this section provides information on how to optimize the probe station for some of the most common measurement challenges.

2.4.1 Grounding, Shielding and Isolation for DC/RF Measurements

The quality and repeatability of DC and RF measurements is greatly influenced by the integrity of the ground system. Components of the probe station are integral to the overall ground system, but so are signal sources and meters making the actual sample measurements. Careful consideration should be given to how these components work together when setting up any experiment. The following sections describe features of the probe station that relate to grounding, shielding and isolation, with some suggestions on how to use them effectively.

2.4.1.1 Ground Reference

The ground reference of a measurement system should be determined first. Signal paths, signal return paths, and shielding build off of that foundation. In most cases earth ground is the ground reference for the experiment. The vacuum chamber is typically tied to earth ground to form a shield around the sample and probes. The CPX is configured this way if it is assembled according to the instructions in Chapter 3. The shield conductor in one of the temperature controller cables is used to give the chamber a low impedance path to earth ground (FIGURE 2-24).

Grounding the vacuum chamber through the instrument console is not appropriate for all experiments, so the connection is designed so that it can be changed easily. The outer shell of the BNC and triax signal connectors and FT-BNC feedthrough connector are electrically connected to the vacuum chamber. Any one of these connectors can be used to establish a ground reference through the measurement electronics if the ground connection to the instrument console is removed.

NOTE

If the vacuum chamber ground reference connection is removed from the instrument console, it is important to reestablish the ground reference through the measurement instrumentation. Leaving the chamber ungrounded often causes unpredictable measurement results.

The probe station refrigerator and included grounded sample holder are also electrically connected to the vacuum chamber. This will ground the back side of the sample substrate during normal operation. The quality of this ground is very dependent on sample mounting technique. Optional sample holders are available to completely isolate the sample if necessary.

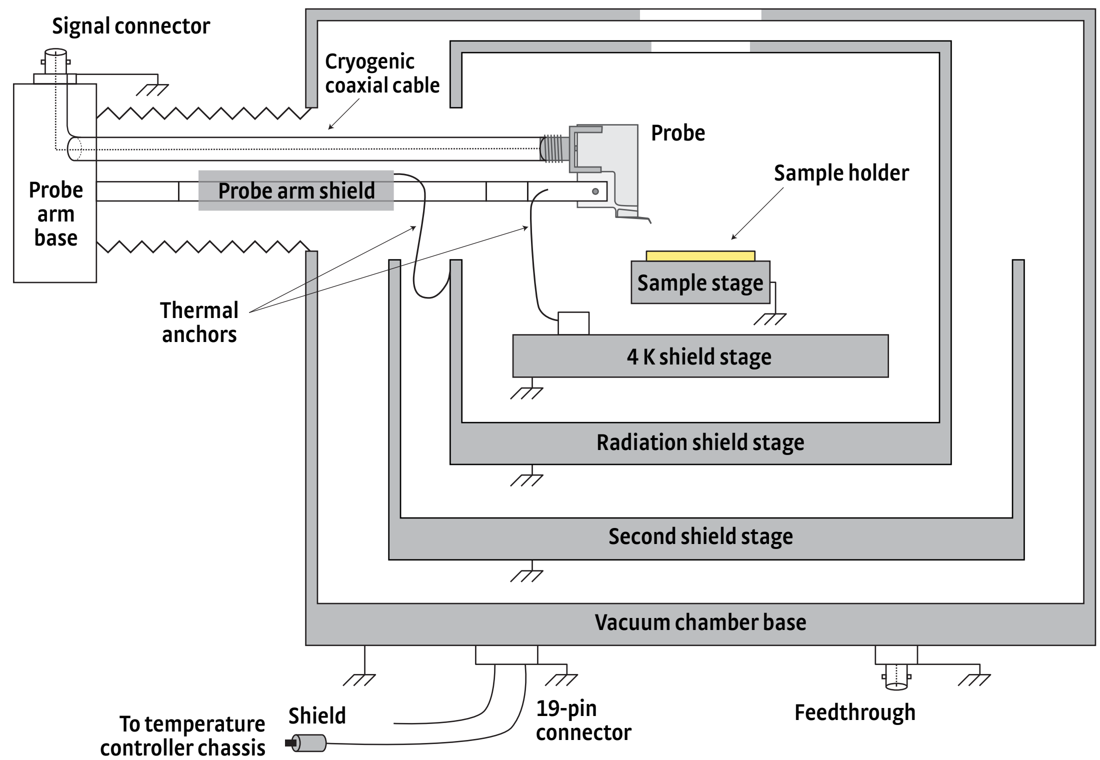


*FIGURE 2-24 **DC/RF ground reference***

2.4.1.2 Avoiding Ground Loops

Ground loops are one of the most common noise sources in measurement systems like a probe station. A ground loop occurs when two or more places on the probe station are connected separately to ground. The loop area is exposed to magnetic fields generated by AC power lines in the lab. The changing field induces line frequency noise in the loop that can permeate through the measurement setup.

As mentioned in section 2.4.1.1, there are multiple places on the probe station that connect electrically to the vacuum chamber, and therefore, have the potential to form a ground loop. Most of these points are connected to provide high frequency shielding for the measurement signals. The shield connections can be the source of line frequency noise if they are allowed to create a ground loop.

Minimizing the effect of ground loops can be difficult—some experimentation may be required to achieve the best results. One of the biggest difficulties is that signal sources and acquisition electronics often operate with one lead internally referenced to earth ground, so the overall grounding system must take this into account.

The best approach is to make the system a poor receiver for the noise:

WARNING

Never remove earth safety ground protection from electronic equipment.

1. Electrically isolate any parts of the systems that do not require grounding for safety or performance.
2. Attach cable shields at only one end of the cable if the shield conductor is not being used to establish a return path for the signal.
3. Add resistance in series with reference ground leads in cases where some common mode voltage is present.
4. Reduce the loop area of any ground loops that remain by routing cables close together or twisting wires.
5. Make sure power lines to equipment have a direct, low impedance path to earth ground so that no voltage is present between equipment grounds.
6. Ground strap instrumentation chassis to provide low impedance between components of the system.

2.4.1.3 Shielding

Shielding reduces noise induced in the probe cables by electric fields in the environment or other equipment in the experiment. The probe station's vacuum chamber is the most important part of a shielding system. The electrically conductive chamber surrounds the sample area and is often connected to the measurement system's ground reference as described in section 2.4.1.1 . BNC and triaxial signal connector shells are electrically connected to the chamber to provide a shield contact for cabling. DC/RF probe cables are all made from cryogenic, coaxial wire so the shielding can be carried inside the chamber and down the probe arm. Outside the chamber, shielding is recommended for all signal cables, but the shielding must not be allowed to create ground loops as described in section 2.4.1.2. It is often necessary to connect the shield at only one end of the cable.

2.4.1.4 Noise Isolation

Every attempt was made in the design and construction of the CPX to isolate potential noise sources so they do not interfere with measurements. It is important to recognize these features so they are not inadvertently defeated when the probe station is re-configured or set up for measurements. Non-conductive components are used to attach the vacuum isolation valve to the vacuum chamber to prevent electrical noise emanating from the pump from entering through the vacuum line (bellows). The temperature sensors and control heaters are electrically isolated from the refrigerator to prevent interference from the instrumentation. This isolation is sufficient for most probe station applications. Additional precautions may be necessary for very low noise measurements; see section 2.4.6.

2.4.2 Basic DC Electrical Measurements

The most common DC configuration consists of BNC signal connectors, ultra-miniature cryogenic coaxial cable and a grounded sample holder. The grounded sample holder provides a direct electrical and thermal contact to the sample stage. This is the most basic measurement configuration, and it suits the needs of many DC research applications (FIGURE 2-25).

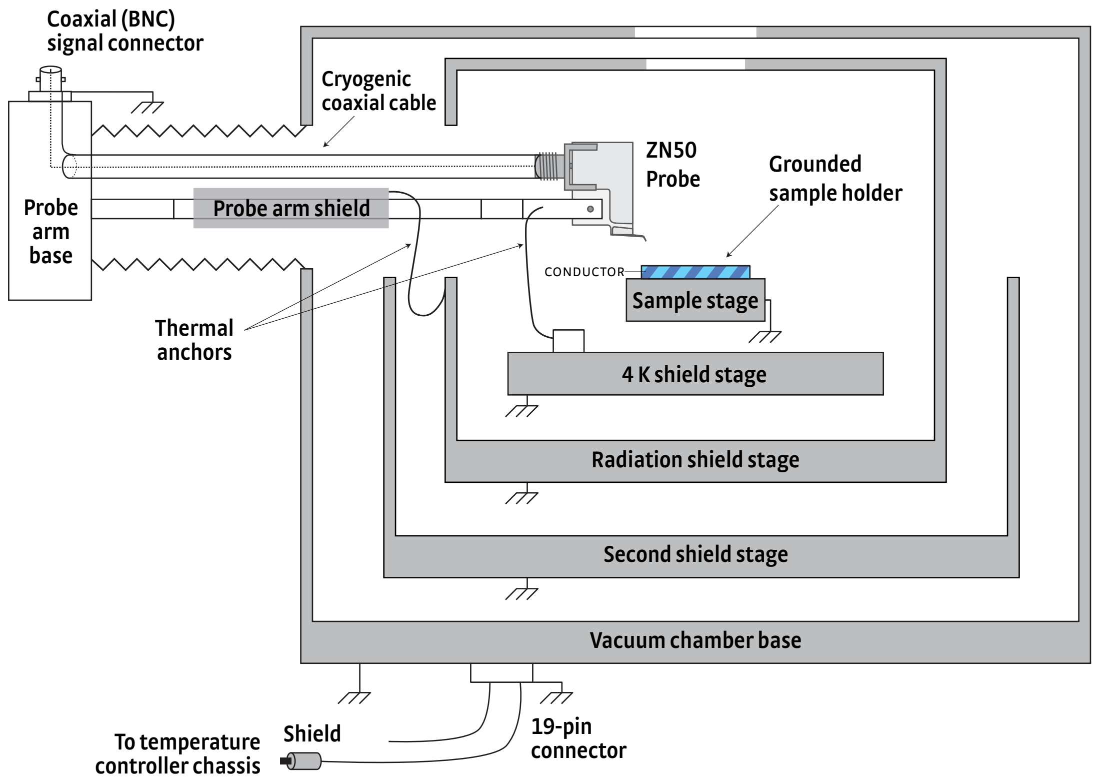


FIGURE 2-25 ***Basic configuration for DC measurements***

2.4.3 Basic RF Electrical Measurements

RF measurements can be made with similar configurations described for DC measurements in section 2.4.2. RF measurements are typically configured with either a BNC signal connector with ultra-miniature cryogenic coaxial cable or a K-connector with semirigid cable as described in section 2.3.2.2. The useable frequency range of a ZN50 configured with a BNC signal connector with ultra-miniature cryogenic coaxial cable is DC to 50 MHz. While performance beyond 50 MHz is certainly possible, steps should be taken to understand the losses at the particular frequency of interest.

The useable frequency range of the ZN50 configured with K-connectors and semirigid cables provides continuous operation up to 100 MHz and selected band operation up to 1 GHz. This configuration has reasonable frequency response out to 1 GHz as long as the band between 200 MHz and 400 MHz can be avoided.

FIGURE 2-26 can add additional information; it shows the forward transmission response of a pair of ZN50 probes configured with K-connectors and semirigid cable. While the probes do have a response out to 1 GHz, the separation of the ground path from the single signal tip of the ZN50 blade causes a large dip in transmission (forward gain) at 0.3 GHz (300 MHz). Depending on the configuration of the probes and measurement setup, this dip can vary from approximately 200 MHz to 400 MHz.

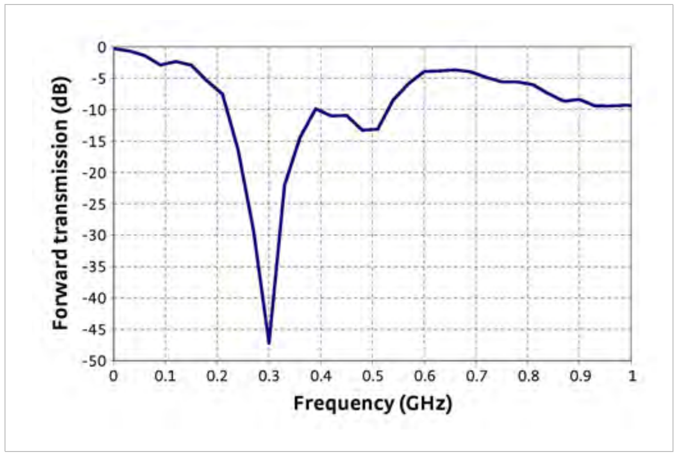


FIGURE 2-26 ***Typical forward transmission response of a pair of ZN50 probes configured with K-connectors and semirigid cable***

2.4.4 Conductive Back Side Features

Special consideration must be given to the choice of a sample holder if the sample is constructed with conductive features patterned on the back side of the substrate. Lake Shore offers optional isolated sample holders that have a non-conductive top surface for this application. Isolated sample holders also work for samples constructed on a uniformly conductive substrate. However, coaxial sample holders should also be considered for this case as described in section 2.4.5.

FIGURE 2-27 ***Isolated sample holder***

2.4.5 Back Side Voltage Biasing

Experiments such as device characterization often require voltage biasing. The biasing voltage can be introduced through a probe if the bias contact is available on the top surface, but doing so prevents the use of the probe for other purposes. Voltage biasing can be done through the sample holder if the bias contact is available on the back side of the sample or if biasing is done directly through the substrate. An optional coaxial sample holder and FT-BNC feedthrough and cable configuration allows convenient back side biasing as illustrated in FIGURE 2-28.

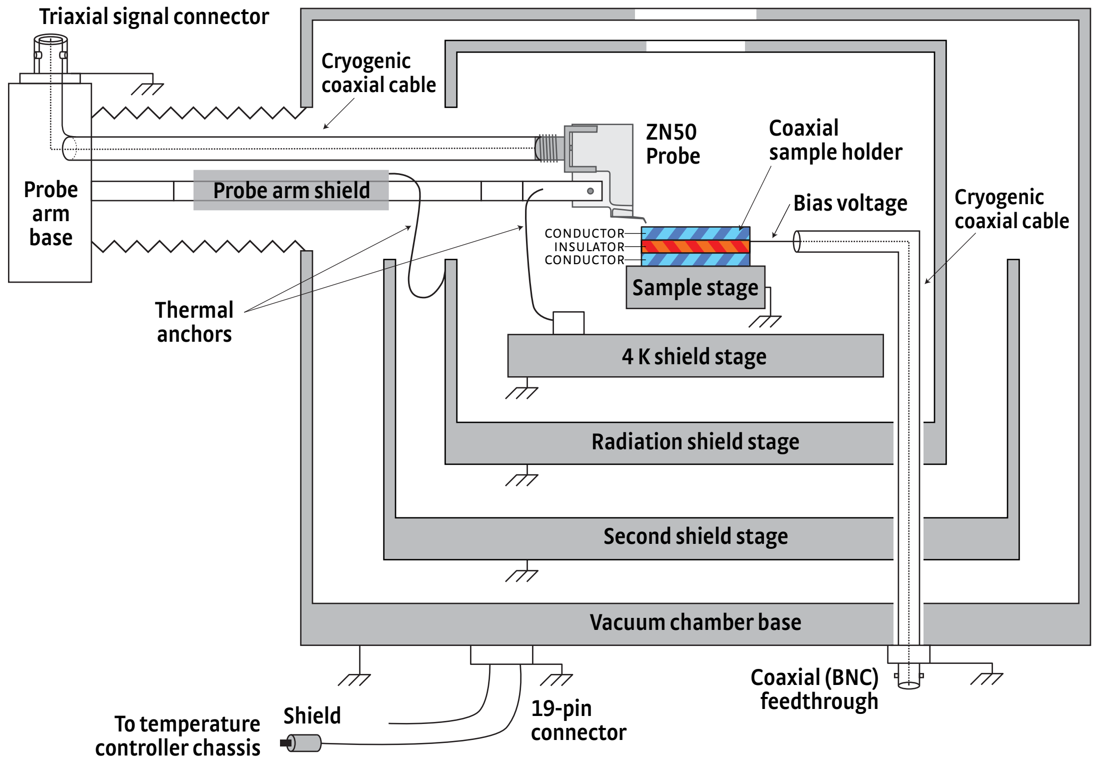


FIGURE 2-28 ***Back side voltage bias with coaxial sample holder***

2.4.6 Small Signal/Low Noise DC/RF Measurements

As measured signal magnitude decreases, environmental noise becomes more of an issue. Proper setup of the experiment is crucial to extracting small signals from the background noise. The CPX offers several standard features and optional configurations that can help.

2.4.6.1 Noise Isolation for Low Noise Measurements

The noise isolation features described in section 2.4.1.4 may be insufficient when making low noise measurements. Please consider the following when setting up a low noise experiment.

WARNING

Never remove earth safety ground protection from electronic equipment.

1. Make every effort to isolate other noisy components (pumps, compressors, switching power supplies) when they are added to the system.
2. Electrical and electronic devices are connected through the power line (mains) even when isolated in the probe station. Care must be taken to prevent noise from coupling through the power connection or earth safety ground.
3. AC noise can enter the measurement through electrical or magnetic coupling even when the leads are isolated. Shielding (section 2.4.1.3) and sample isolation (section 2.4.6.2) should also be considered.

2.4.6.2 Sample Isolation for Low Noise Measurements

Even with proper setup and isolation of the electronics, it is sometimes impossible to reduce their interference with the sample when it is mounted on a grounded sample holder. One solution is to use an optional coaxial sample holder to isolate the sample from the grounded refrigerator and vacuum chamber. The FT-BNC feedthrough and cable configuration can be used to bring a clean measurement ground reference directly to the sample plane. This configuration can both isolate and shield the sample (see FIGURE 2-28).

2.4.6.3 Additional Considerations for Low Noise Measurements

When designing a small signal or low noise experiment it is important to consider more than the electronics. There are environmental factors that can limit measurement quality as well. Three of the most common are:

1. *Contact quality:* poor probe to sample contacts can cause noise, drift and poor repeatability in measurements. Refer to section 2.6 for information on how to improve contact quality.
2. *Temperature stability:* the sample temperature changes relatively slowly in most applications and often does not contribute to measurement noise. Small signals tend to have longer measurement intervals due to averaging so they are more susceptible to temperature changes. It is important to properly tune the temperature controllers to improve temperature stability. It is also important to allow the system to stabilize at the desired temperature longer before taking data. It often takes several minutes after the sample stage temperature sensor stabilizes before the sample comes to equilibrium.

NOTE **Cryogenic experiments are most often designed to cool the system to base temperature first. Temperature is then increased between data points to provide the best sample temperature stability.**

3. *Vibration isolation:* the vibration present in a typical probe station seldom contributes to measurement noise unless the probe to sample contact is poor. When making small signal measurements, the effect of vibration increases. The slight change in contact resistance due to the vibration is larger compared to the signal. Other noise sources such as the triboelectric effect in the probe cables can also become meaningful. Lake Shore offers optional vibration isolation for probe stations and options for isolating vacuum pump lines that have the potential to induce vibration into the system.

2.4.7 Measuring Low Resistance

One application that produces small, difficult to measure signals is probing low resistance samples. It is tempting to simply increase excitation current to increase the signal voltage above the noise floor. However, in cryogenic systems like the CPX, this can lead to unwanted heating of the sample. AC measurement techniques like those used in lock-in-amplifiers are preferred in cryogenic applications because they can separate the signal from noise without excessive current. Lake Shore offers the industry leading Model 370 AC resistance bridge for this and other low power resistance measurements. For the ultimate low noise performance, the optional Model 3708 preamplifier for the Model 370 has an input noise specification of 2 nV/√Hz.

2.4.8 High Impedance/ Low Leakage Measurements

The CPX can accommodate resistance measurements greater than 100 GΩ, but not without special consideration given to probe station configuration and external electronics. High impedance measurements are difficult for several reasons. The current used to excite the sample must be very small, so even tiny amounts of leakage current can create a large percentage reading error. High resistance lead arrangements are more susceptible to environmental fields, which easily induce current noise. Probe to sample contacts are difficult to establish and verify.

2.4.8.1 Grounding and Shielding

A general discussion of grounding and shielding is in section 2.4.1. These concepts become more important for high resistance measurements. High resistance samples do not short circuit induced noise the way low resistance samples do. When measuring high resistance, measurement electronics tend to convert common mode noise, which is easily cancelled, to normal mode noise, which is difficult to separate from the signal.

2.4.8.2 Driven Guards

Driven guards are used to minimize the leakage current that typically flows between conductors in the leads used to connect the sample to measurement electronics. The most common leakage path is between the signal leads and their respective shield or ground. Properly configured, a guarded measurement system can reduce leakage current by three orders of magnitude or more, which would allow a system capable of accurately measuring 10 MΩ to 100 MΩ to measure 10 GΩ to 100 GΩ.

Guarding works by surrounding signal leads with coaxial conductors and driving them with a guard voltage close to the signal voltage. Very little current crosses the insulation resistance leaks, because the voltage difference is low. Guarding does not provide adequate shielding so the signal and guard are often surrounded by a shield, requiring triaxial cable and connectors (FIGURE 2-29).

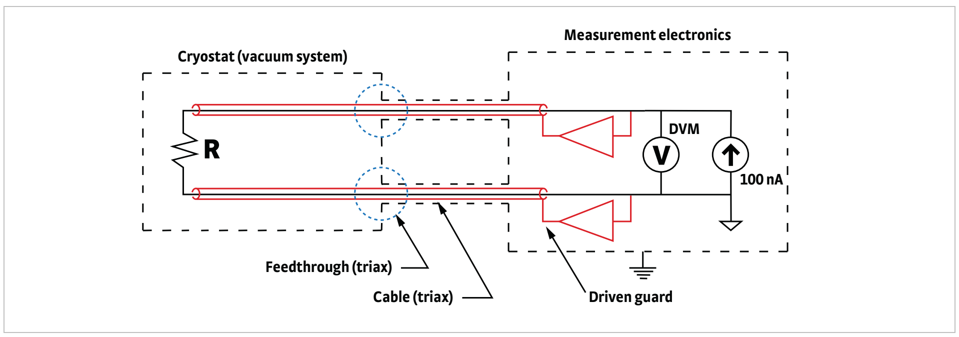


FIGURE 2-29 ***Recommended circuit for measuring high-resistance devices***

The entire experiment must be set up with guarding in mind. A key element of most guarded systems is the excitation source. Keithley Instruments Model 6220 DC precision current source is an excellent example of a guarded source that can combine with a precision voltmeter or electrometer to make high resistance measurements. The critical elements needed to carry the guarding inside the probe station are described in section 2.4.8.3.

2.4.8.3 Guarded Probe Station Configurations

Within the probe station, guarded configurations begin with triaxial signal connectors , which are part of the ZN50-T, DC/RF cable configuration for probe arms.

FIGURE 2-30 ***Triaxial connector***

1. The center pin carries the signal. It is connected internally to the center conductor of the cryogenic, coaxial cable that is attached to the ceramic blade signal conductor and probe tip.
2. The middle ring carries the guard voltage. It is connected to the outer conductor of the cryogenic, coaxial cable that is attached to the ceramic blade reference plane.
3. The outer shell is available for shielding the external cable. It is connected to the vacuum chamber. The shield is not carried inside the vacuum chamber in this configuration. The chamber itself provides shielding.

For best performance, the sample must be guarded in addition to the cables. There is a potential leakage path through the sample substrate to a standard grounded sample holder. The SH-1.25-C or SH-2.00-C coaxial sample holder is recommended for guarding samples in the CPX. The FT-BNC coaxial feedthrough is used to bring the guard voltage into the chamber and to the sample holder. When the experiment requires guarding and back side voltage biasing or additional ground isolation, the SH-1.25-T or SH-2.00-T triaxial sample holder is required in the CPX.

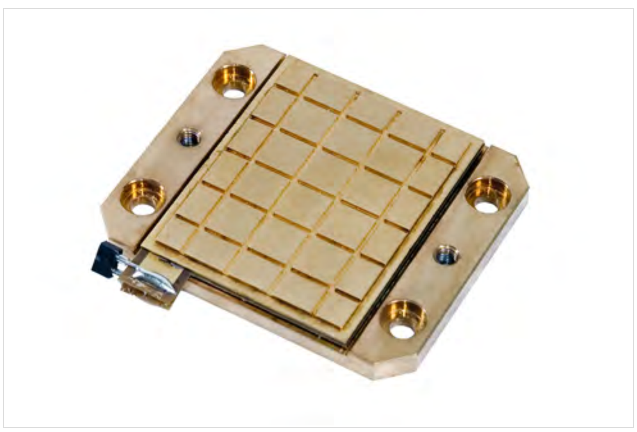


FIGURE 2-31 ***Triaxial sample holder (SH-1.25-T)***

The triaxial sample holder offers two layers of isolation between the sample and grounded refrigerator. The FT-TRIAX triaxial feedthrough is required to connect signals to the sample holder (FIGURE 2-32).

NOTE **The coaxial and triaxial sample holders are almost identical in appearance; however, the difference is the number of electrical isolation layers, which cannot be seen from the outside.**

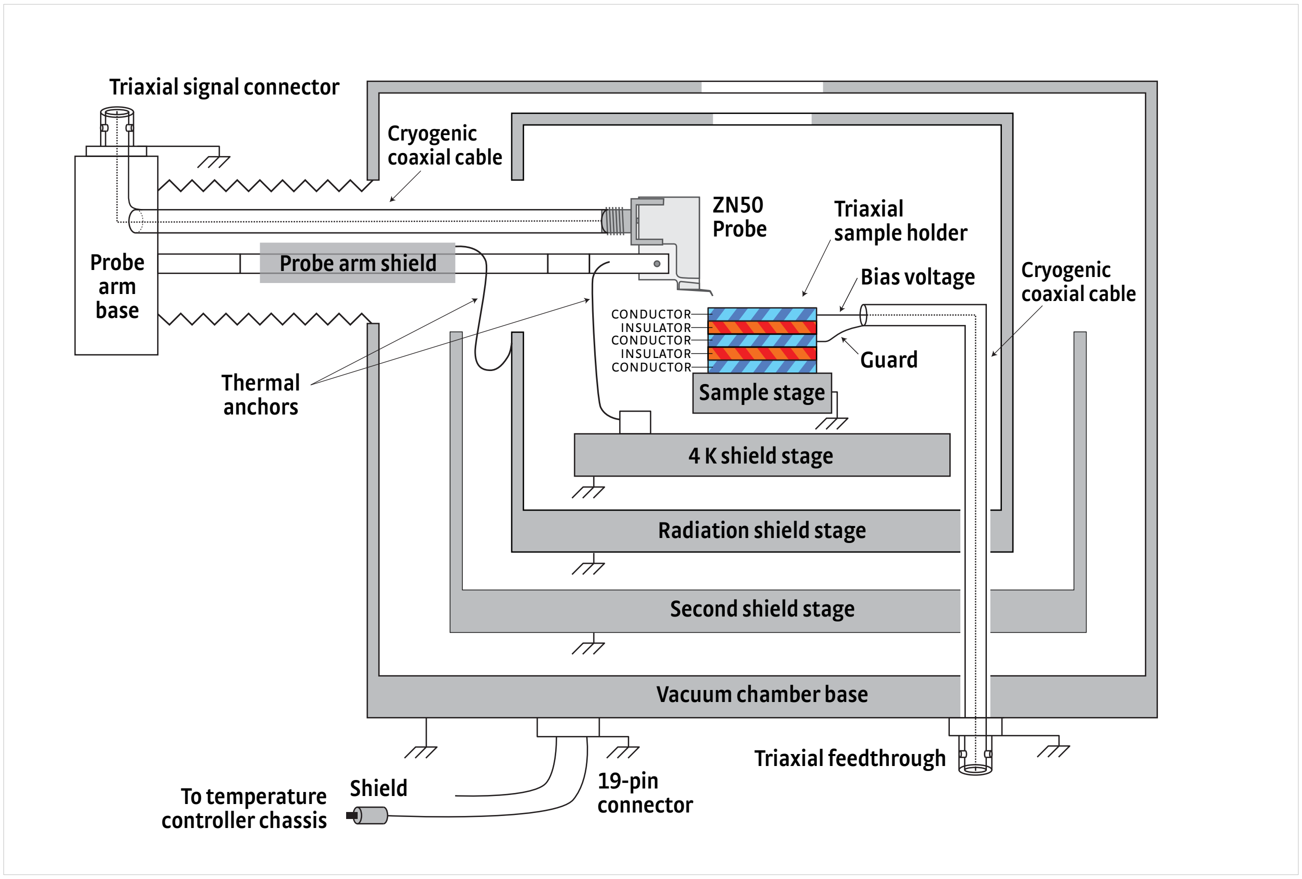


FIGURE 2-32 ***Guarding with back side voltage bias***

2.4.8.4 Measurement Voltage Limits

The CPX probe station is specified for signal voltages below 60 VDC and 30 V_{rms}, referred to as non-hazardous live voltage. The sensor, heater and power supply voltages entering the probe station are all below this voltage. More importantly, testing criteria established for the CE mark assumes there will be no hazardous live voltage operating in the probe station.

Many of the guarded sources, electrometers and other pieces of electronic test equipment used in DC or RF measurements are capable of operating from hundreds of volts to over thousands of volts. The CPX probe station is not specifically designed to ensure operator safety when these voltages are present.

WARNING

Because Lake Shore has no way to predict how the hazardous live voltages would be configured or operated, it is impossible for us to guarantee safety in the event of improper operation, accidental misconnection or component failure. The CPX does not include the safety interlocks, current limits or earth safety ground system that are necessary for safely working with hazardous live voltages.

2.5 Considerations for Microwave Measurements

Lake Shore offers microwave configurations with ground-signal-ground (GSG) probe geometry optimized for substrates patterned with coplanar waveguide structures. Both signal and ground traces of the microwave structures must be patterned on the top layer of the substrate to facilitate top side probing. Measurements can be performed on both passive and active devices to characterize performance metrics such as S-parameters, noise figure, or load-pull parameters.

Proper use of GSG microwave probes is more complex than of DC/RF probes. Proper probe alignment of the GSG points with respect to the test substrate is required, as is the proper probe planarization with respect to the plane of measurement. Also, calibration may be desired to separate the frequency dependent losses of the measurement setup from the actual device under test.

The remaining sections in this chapter describe details of the microwave probe measurement setup, as well as concepts and techniques that are important for making good microwave measurements in the probe station.

2.5.1 Microwave Cables and Connectors

Microwave cables form transmission lines that carry high frequency signals from the signal connection point outside the vacuum chamber to probe points near the cooled sample. The type and quality of microwave cables and their associated connectors determine the frequency range and overall performance of microwave measurements in the probe station. Properly installed, the cables provide a low loss, broad band electrical path with minimal crosstalk. Also, they need to be compatible with the cryogenic temperatures and vacuum for the CPX.

The geometry of the CPX requires that the cables extend 229 mm (9 in) into the vacuum chamber with a single 90 degree bend. The total length of the microwave cable is approximately 279 mm (11 in). Probe station layout inherently contributes some signal loss. Lake Shore recommends the following for best performance:

1. Calibrate the system as described in section 2.3.8.7.
2. Retighten the connectors to manufacturer's specified torque after repeated thermal cycling.
3. Keep external cables as short and direct as possible.

Microwave probes must be specified with the same frequency and connector type as the probe cable. TABLE 2-4 summarizes the three microwave probe frequency ranges and associated connectors.

Highest rated frequency	Connector	Mates with
40 GHz	K-type (2.92 mm)	Standard SMA connectors
50 GHz	2.4 mm	V (1.85 mm) connectors
67 GHz	V-type (1.85 mm)	2.4 mm connectors

TABLE 2-4 ***Microwave probe frequency ranges and associated connectors***

For reference, FIGURE 2-33 to FIGURE 2-35 show plug and socket, head-on views of the three types of connectors. Note that all three types look very similar. Side by side, differences in the connectors can be seen primarily in the head-on view in the thickness of outer conductor and spacing between the inner and outer conductor.

CAUTION **The connector types are physically similar and can sometimes, but not always, be interchanged; care should be taken not to damage probes or cables by attempting to mate them improperly.**

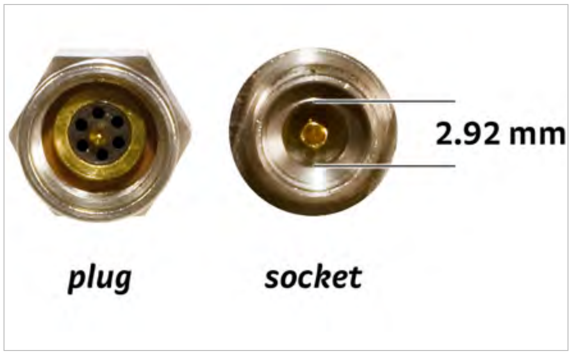


FIGURE 2-33 ***K-type (2.92 mm) connectors— published mode free to 40 GHz***

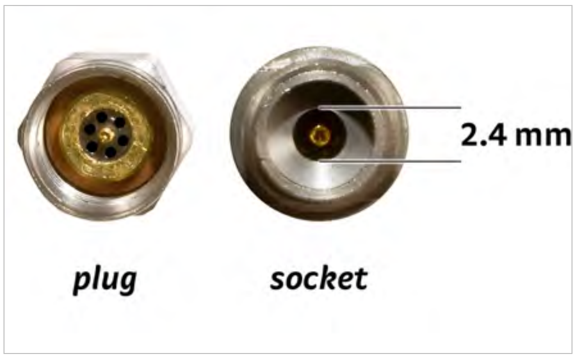


FIGURE 2-34 ***2.4 mm connectors — published mode free to 50 GHz***

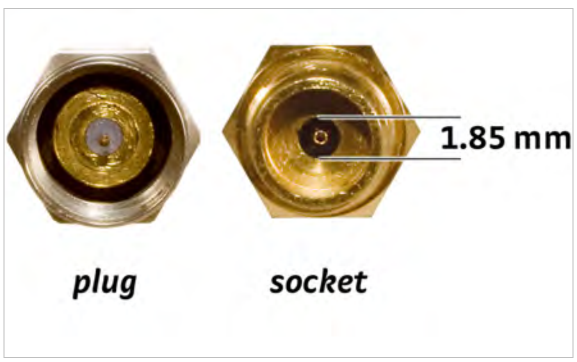


FIGURE 2-35 ***V-type (1.85 mm) connectors— published mode free to ~67 GHz***

2.5.2 Ground Return Path

A microwave probe cable consists of a microwave semirigid coaxial cable with connectors permanently mounted on each end. The center conductor is the signal path and extends to the center point on the probe tip. The outer conductor is the reference ground path and extends to the two outer points of the GSG probe tip.

The outer conductor is also electrically connected to the microwave probe body so the measurement reference ground is electrically connected to the refrigerator through the probe mount braids. Keep in mind that this electrical connection may be broken if desired by removing the anchors from the CPX 4 K shield stage; however, please note that this will also remove the thermal connection.

2.5.3 Pad Construction and Impedance Matching

The three points of a GSG microwave probe tip extend the 50 Ω impedance of the semirigid transmission line down to the test substrate. The landing pads on the measurement substrate should be 50 Ω impedance coplanar waveguide structured. If the substrate being tested has an impedance of something other than 50 Ω, the microwave signal will experience a discontinuity at the transition, which will result in some of the energy being reflected back to the signal source.

Minimum pad size of 50 μm × 50 μm is recommended for proper probe landing, with the spacing between the pads determined by probe pitch. It is recommended to skate the tip forward approximately 15 μm to 25 μm for good electrical contact. Gold plating is recommended to obtain consistent ohmic contacts for each point.

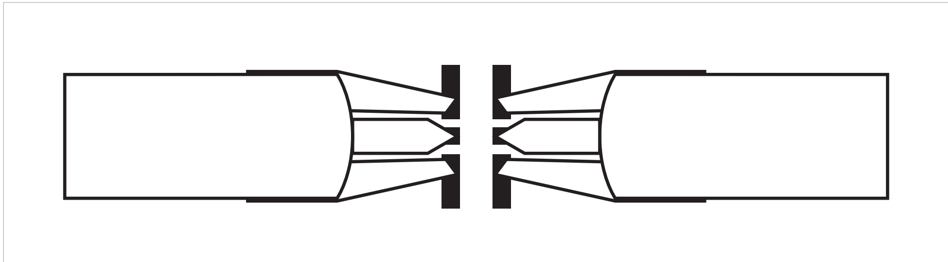


FIGURE 2-36 ***Probe tip and pad geometry***

2.5.3.1 Probe Crosstalk

In the GSG probe construction, the ground points on either side of the signal point help keep the microwave signals contained between them, which minimizes crosstalk between adjacent probes. Probe tips that are properly landed on measurement pads that have 50 Ω impedance radiate very little signal. Poorly landed or open probe tips radiate significantly more. Therefore, properly land or move away any active probes that are not involved with the measurement or calibration.

Probes that are oriented across from each other (in-line) have higher crosstalk coupling than probes oriented at 90 degrees. To illustrate this, FIGURE 2-37 shows the frequency response of a pair of 67 GHz microwave probes landed on the 50 Ω pads of a CS-5 calibration substrate and located approximately 150 μm directly across from each other. The S12 and S21 transmission coefficients show the crosstalk between the probes in this in-line (worst case) configuration of -10 dB across the entire frequency band. This crosstalk should be negligible for most measurements; however, if the devices to be measured require in-line probe-to-probe placement less than 150 μm, crosstalk could affect the accuracy of the measurement.

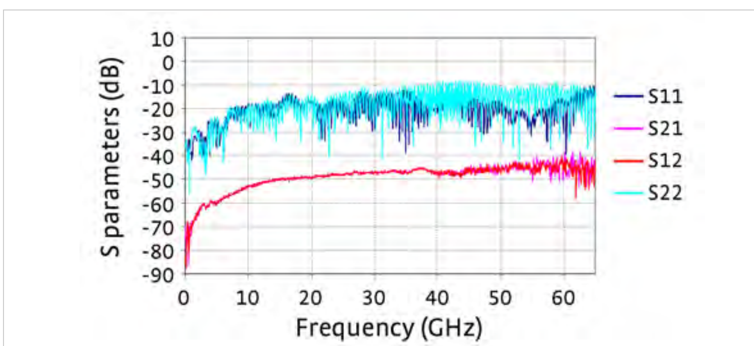


FIGURE 2-37 ***Frequency response of 67 GHz microwave probes located 150 μm across from each other and landed on the 50 Ω pads of a CS-5 calibration substrate***

2.5.4 Calibration with the CS-5 Calibration Standard

The following concepts are used with permission from the CS-5 instructions.
For the most accurate microwave measurements using a vector network analyzer (VNA), calibration is required to eliminate the frequency dependent losses of the associated connectors, cables, and probe tips. The CS-5 or CS-15 calibration substrate can be used for this purpose. The CS-5 can be used for pitch ranges of 75 to 250 µm and the CS-15 can be used for pitch ranges of 50 to 150 µm.

Standard elements for calibrating a microwave measurement system consist of opens, shorts, matched loads, and throughs. These four elements have electrical characteristics that are very different from one another, so that each one by itself contributes an important part to the calibration.

FIGURE 2-38 shows the response of a pair of 67 GHz probes placed on a 50 Ω through test structure on the CS-5 calibration substrate. The measurements were made using a commercial VNA calibration (using mechanical standards) that places the measurement reference plane at the end of the VNA measurement cables that are connected to the input connectors of the 67 GHz probe arms. FIGURE 2-38 shows the frequency dependent characteristics of the probe station with the 67 GHz probes and probe arms. The performance looks very good, with the transmission coefficients S21/S12 remaining above -10 dB and the reflection coefficients S11/S22 remaining below -10 dB over the entire frequency band. The gradual sloping increase in loss (the decrease in S21/S12) as the frequency increases is expected.

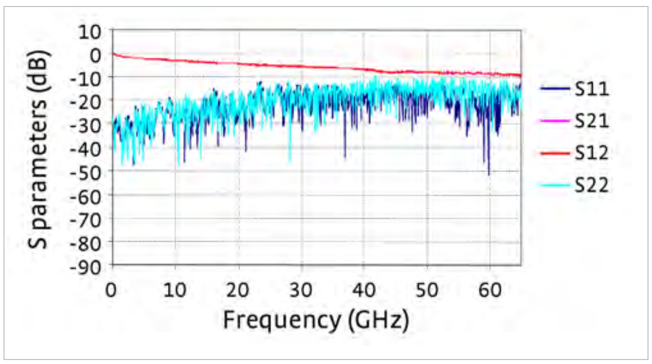


FIGURE 2-38 ***S-parameter response of 67 GHz GSG microwave probes***

FIGURE 2-39 shows the response of a pair of 67 GHz probes placed on a 50 Ω through test structure following a SOLT calibration using the CS-5 calibration substrate. This calibration places the VNA measurement reference plane at the end of the probe tips, and thus, removes the losses of the associated cabling and probes from the measurement response of an unknown substrate.

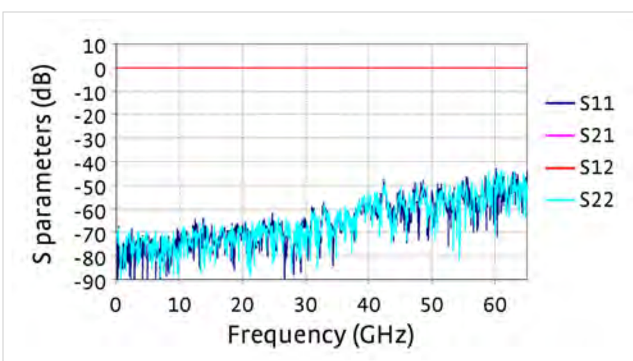


FIGURE 2-39 ***Calibrated S-parameter response of 67 GHz GSG microwave probes***

2.5.5 Temperature Effects of Calibration

There are temperature dependent losses in microwave feedthroughs, semirigid cables, and probe bodies and tips. As the sample stage cools to 4.2 K, for example, there is approximately a 294 K temperature gradient set up over the length of the semirigid coaxial cable. In addition, the structures of a calibration or test substrate have a temperature dependent response. Measurements have shown that there is approximately 1 to 2 dB less insertion loss at 67 GHz as measured in S21/S12 at 4.3 K compared to the same measurement at 300 K.

To illustrate this phenomenon, FIGURE 2-40 shows the calibrated S-parameter response of a pair of 67 GHz GSG microwave probes measured on a 50 Ω through structure at 4.3 K temperature using a SOLT calibration that was performed at 300 K temperature. Note the error in the calibration as compared to FIGURE 2-39. The error is due in part to the temperature changes in the arms and probes, as well as the coplanar waveguide physically changing geometry, which causes errors in the VNA calibration correction coefficients. The calibration error is on the order of 1 to 2 dB for this particular calibration that spans 40 MHz to 67 GHz and represents a 294 K temperature change from the calibration temperature to the measurement temperature. This example represents a wide band measurement over a large change in temperature and is described here as an extreme case; the error will be less for narrower band measurements or for measurements over smaller temperature variations. For the most accurate measurements, it is recommended to perform a calibration at the actual measurement temperature.

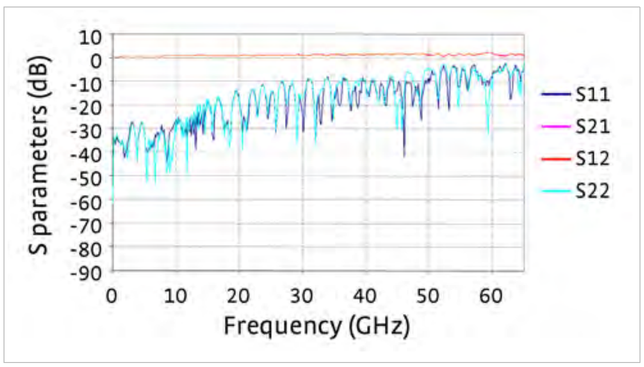


FIGURE 2-40 ***Calibrated S-parameter response of 67 GHz GSG microwave probes measured on a 50 Ω through structure at 4.3 K after calibration with a CS-5 substrate at 300 K***

2.5.6 Planarization

Another concern with microwave probes is that the probe must be rotated to ensure that the three points of the probe (ground, signal, and ground) are in the same plane as the sample; this is referred to as planarization.

FIGURE 2-41 shows the S-parameters for a probe station before and after the contacts are properly planarized and good contacts established.

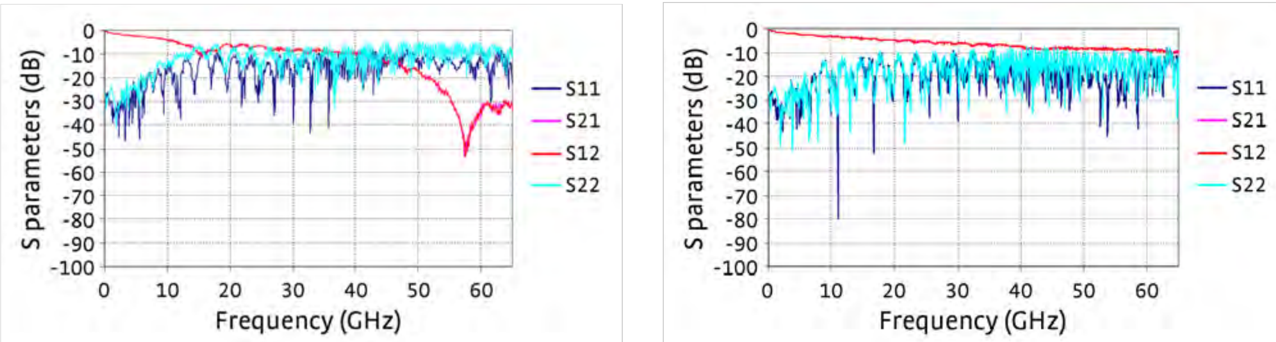


FIGURE 2-41 ***Left: Improperly planarized test with poor contact—uncalibrated response; Right: Improvement shown in the S-parameters after proper planarization and quality contact—uncalibrated response***

2.6 Contact Quality

The movable probe tip contacts that make probe stations such flexible tools can also lead to poor measurement repeatability if contact quality is poor. Low resistance, ohmic contacts are the goal for most electrical measurements. The following topics should be considered when establishing contacts and testing their quality.

2.6.1 Contact Material

The most repeatable probe contacts are formed between the metal probe tip and a metal pad patterned on the sample. Contacting other materials like bulk semiconductors requires special considerations not covered in this manual. Gold plated metal is the most common pad material used in probe station applications, but any conductive metal that resists oxidation or reaction with the tip metal can be used to form low resistance contacts. Lake Shore offers three probe tip materials that are compatible with different probing applications (see section 2.3.2.1).

2.6.2 Contact Area

In addition to contact material, contact area is a major factor in the ultimate contact resistance. Lake Shore offers probe tips with a variety of radii. In general, a larger tip radius will create a larger contact area, but this may not translate to lower contact resistance, as several factors dictate how much surface is actually in contact.

Focusing on the metal to metal interface, the true nature of the surfaces is not smooth, but rough. It would not be unusual for this roughness to be 1 μm or 2 μm. Surface roughness causes the actual contact area to be much smaller than the physical contact area because conduction is through a few asperities (high points). The use of soft pad materials and steady contact pressure can minimize the effect of surface roughness.

Probe contamination is another factor that can reduce contact area. Any foreign material picked up on the probe tip will prevent metal to metal contact. Probes should always be handled with gloves and stored in their original shipping containers when not in use to prevent contamination. Probes also cold weld pad metal to themselves after repeated landings. Nonconductive materials are frequently attached to the pad material, causing contamination. Probe tips should be cleaned regularly to remove contamination. Cleaning instructions are given in section 6.2.7 and section 6.2.8.

2.6.3 Oxidation

Oxidation is probably the biggest source of poor contact resistance in a well maintained probe station. Oxidation builds up on the probe and pad metals over time to form an electrically insulating layer that prevents metal to metal contact. The light oxidation that forms between routine uses can normally be wiped clean when the probe is landed. If the probe or pad is allowed to form a thick oxide film (tarnish), more aggressive action is necessary. Pre-cleaning or over-travel of the probe tip (scratching) may be required to create forces large enough to break the film. The larger, softer tips that help increase surface area may not be as good at scratching through oxidation; therefore, a compromise is often necessary. Controlled electrical current can also be used to break through any remaining insulating barrier.

2.6.4 Four-Lead Measurement

A four-lead measurement technique is frequently used during resistance measurements to eliminate the effect of unwanted contact and lead resistance. In this technique, the two excitation current leads are separated from the two voltage measurement leads all the way down to the probe tips. A reasonable amount of contact resistance and small changes in contact resistance will not appear in the voltage measurement because there is no current flowing through the voltage contact. However, this technique will not overcome contacts that have too much resistance or are non-ohmic.

2.6.5 Ohmic versus Non-ohmic Contacts

Ohmic contacts result from a good interface between two conductive surfaces. They are called ohmic because they exhibit a linear relationship between current and voltage, like a resistor. Non-ohmic contacts are typically formed when oxides or other contamination is present between the conductive surfaces. They exhibit a non-linear relationship between current and voltage more closely resembling a diode. This is undesirable because signals resulting from the contact cannot easily be subtracted from the desired signal of the sample.

2.6.6 Measuring Contact Quality

Measuring contact quality is always recommended for critical measurements to make sure the contact resistance is low and the contact is ohmic. Both contact resistance and ohmic behavior can be checked at the same time. The most common DC technique is to excite two probe contacts at a time with different positive and negative currents and plot the measured voltage (IV curve). A linear curve with a low slope indicates a good contact. Non-linearity in the curve indicates a non-ohmic contact. If the test cannot be performed on the actual device, probing technique can be verified by landing two probes on one sample pad and making an IV curve prior to probing the device.

In the case of a microwave measurement, contact resistance increases the series resistance of the microwave circuit. However, the film between the probe and measurement pad can form a capacitor. This capacitance will change the S-parameters of the device as measured by a network analyzer. A level response on the network analyzer is typically the best measure of contact quality.

2.6.7 Lab Protocol

Lake Shore recommends developing a lab protocol to ensure consistent contacts. The protocol should include probe handling, routine cleaning, landing probes and measuring contacts. The probe landing instructions given in section 4.6 describe the action of skating the probe tip on the sample pad. The amount of skate is one of the most important parts of the protocol. More skate provides more wiping to clean away oxidation and more pressure to increase actual contact area. Too much skate will damage the probe tip.

Chapter 3: Installation and Setup

3.1 General

This chapter describes the process of preparing a site, unpacking the probe station components and assembling them into the standard CPX configuration. Finally, it explains system checkout procedures.

3.1.1 Lake Shore Assisted Installation

Lake Shore personnel or trained representatives are available to assist with the installation process. When installation and training services are purchased with the probe station, the customer will be contacted and provided with the CPX site prep form and applications engineer contact information shortly after the order is placed. To avoid delays in the installation process, please read the form carefully as soon as it arrives.

Customers are responsible for completing section 3.2 through the end of section 3.3 before an installation trip can be scheduled.

3.2 Site Requirements

This section describes the space, utilities and equipment that must be provided at the installation site to properly install, test and operate a CPX probe station.

NOTE

Much of the equipment described in section 3.2.3 to section 3.2.6 is not included with a standard CPX probe station or as part of the installation and training service. Some of that equipment can be purchased from Lake Shore as options or accessories; those model numbers are listed in the relevant sections.

3.2.1 Space Requirements and Suggested Layout

The CPX probe station and associated electronics console are relatively compact. However, the vacuum pumping station, cryogen Dewar and transfer line can take considerable space during operation. Some consideration should be given to the floor plan before placing the probe station. The site must have enough space to provide access to all controls without posing a risk to the operator. A suggested floor plan is illustrated in FIGURE 3-1 . The suggested layout can be mirrored or rearranged to fit in the available space. However, the angle of the transfer line and mating bayonet are fixed, and the vacuum pumping station must be within 2 m (79 in) of the vacuum chamber for optimum performance.

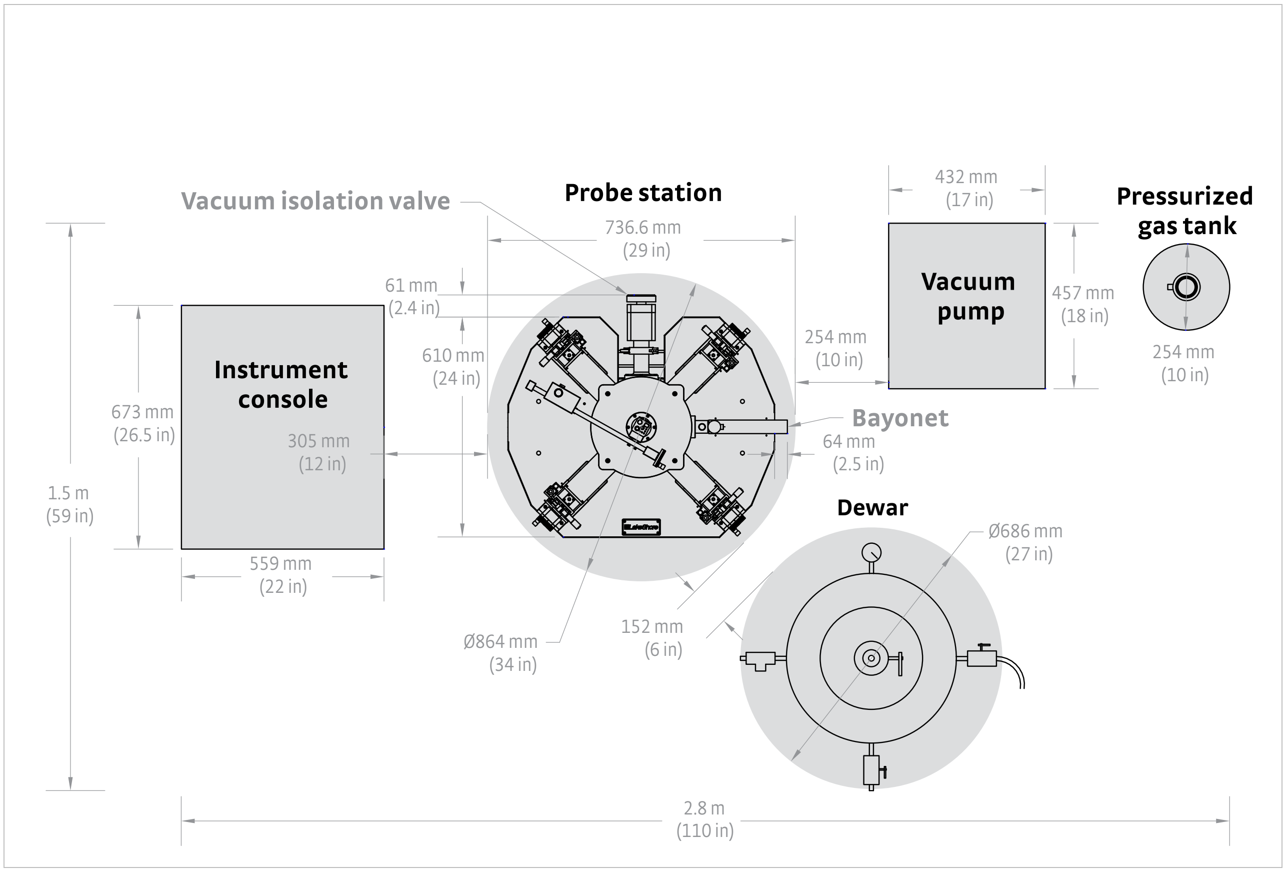


FIGURE 3-1 ***Suggested floor plan***

In addition to the necessary floor space, ceiling height is also a site consideration as illustrated in FIGURE 3-2. Approximately 2.9 m (115 in) from floor to ceiling (or 1.1 m [42 in]from the top of the Dewar to the ceiling) is required to insert the transfer line into the Dewar. If this height is not available at the probe station, the transfer line can be inserted in another room and then transported with the Dewar to the probe station.

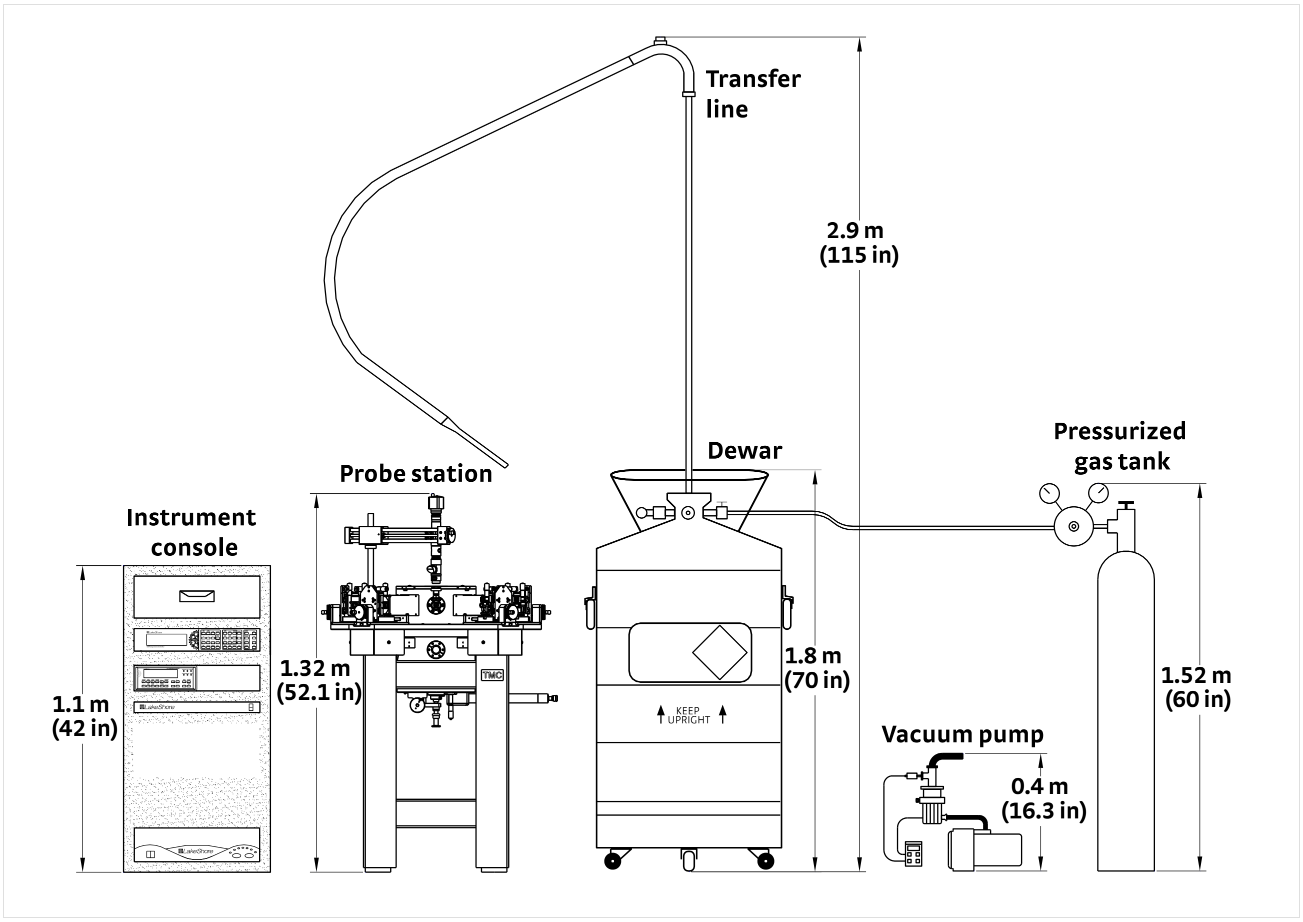


FIGURE 3-2 ***Suggested elevation***

3.2.2 Environmental Requirements and Concerns

There are several environmental considerations that may affect probe station operation, probe measurements or the safety of the user. The following sections discuss vibration considerations, electrical noise, ventilation, and safety considerations.

3.2.2.1 Vibration

Place the probe station away from major sources of vibration to avoid problems when landing probes and to avoid electrically noisy probe contacts. We recommend placing it on a concrete floor, on the lowest floor of the building, and away from elevators, large motors or moving equipment. If floor vibration is a concern, the Lake Shore PS-PVIS vibration isolation system is available to order along with the probe station.

The probe station turbo pumping system can be a source of vibration. The vacuum pump is often turned off when the refrigerator is cooled to below 77 K. Additional vibration isolation may be needed if working outside of that range. The Lake Shore PS-PLVI-40 pump line vibration isolator or equivalent is recommended for reducing vacuum pump vibration.

3.2.2.2 Electrical Noise

Place the probe station away from major sources of electrical noise to avoid interference with probe measurements. Common electrical noise sources in buildings are power distribution panels, high capacity power lines, communications distribution centers and RF (radio) transmitters.

Line power quality can also impact electrical measurements done in the probe station. When possible, avoid long or indirect power routing, circuits that are shared with motors or other noisy loads, unbalanced, overloaded, and poorly grounded circuits. When poor quality power circuits are unavoidable, an isolation transformer for measurement instruments may be required to achieve optimum performance.

3.2.2.3 Ventilation

Place the probe station in a well ventilated area to avoid the risk of asphyxiation from liquid cryogens.

⚠WARNING **Failure to vent large quantities of vaporized cryogen can result in a loss of consciousness or death. Vaporizing cryogen displaces oxygen in its vicinity, presenting an asphyxiation hazard. There is a risk of oxygen deficiency if the oxygen level falls below 19.5%.**

3.2.2.4 Safety Compliance

The system is designed to be used in a laboratory environment; therefore, safety testing is done to laboratory standards. For the CE mark, normal use is defined as: indoor use, altitude to 2000 m, temperature between 5 °C and 40 °C, maximum relative humidity of 80% at 31 °C, and air quality pollution degree 2 (nonconductive pollution of the sort where occasionally a temporary conductivity caused by condensation must be expected).

3.2.3 Power Requirements

Electrical power is required for the operation of the instrument console, vision system, turbo pumping system and optional air compressor. Most equipment is designed to operate over a range of line voltages. Some equipment must be configured to operate at a specific voltage within the range listed. This equipment is configured at Lake Shore to the voltage specified when the equipment is ordered. Refer to section 6.4.1 for additional information on power requirements and configuration options.

The electrical equipment can be grouped as shown in TABLE 3-1 to distribute the system power requirements over multiple facility circuits. TABLE 3-1 details the operational power requirements for each circuit. The turbo pumping station and air compressor should be powered from a separate circuit to isolate electrical noise from the sensitive electronic instruments. It is also recommended that the circuit protection used for the circuits powering the turbo pumping system be capable of handling high inrush currents. The turbo pumping system will draw high inrush currents when powered on. Circuit protection capable of handling these short duration inrush currents is required to prevent nuisance tripping of the safety devices.

	Probe station equipment	Operational current required (AAC)			
		100 VAC	120 VAC	220 VAC	240 VAC
Circuit 1	Instrument console	9.4	6.2	3.8	3.1
	Vision system (monitor, camera and light source)	7.2	6.0	3.3	3.0
Circuit 2	PS-V81DP turbo pumping station	6.2	6	3.1	3
	Air compressor (120 VAC only)	—	2.2	—	—

TABLE 3-1 ***Power requirements***

3.2.4 Cryogen Requirements

The CPX is a cryogen flow (open cycle) refrigerator. Liquid cryogen must flow continuously through the refrigerator during operation. Liquid nitrogen can be used to cool the sample to 78 K, and liquid helium is necessary to cool the sample below 78 K. The system can be used at ambient temperatures for measurements with no cryogens.

The cryogen must be provided in an appropriate Dewar designated for the correct cryogen, either helium or nitrogen. The Dewar must have the following features: 127 mm (0.5 in) top withdraw liquid port, gas port with shutoff valve, and safety pressure relief valves, one of which should be approximately 68.9 kPa (10 psi). The Lake Shore Model PS-LN2 option provides a 50 L nitrogen Dewar.

The CPX can require a cryogen flow rate as high as 4.5 liquid L/h; therefore, a Dewar pressurization system is normally required. Requirements for a gas pressurization system are described in section 3.2.6.

The CPX includes a transfer line capable of transferring either liquid helium or liquid nitrogen from the Dewar to the probe station. The transfer line supply leg is approximately 1.7 m (5.5 ft) long (refer to FIGURE 3-2).

NOTE **You will need to provide 60 L of liquid helium during installation. This amount is needed to demonstrate the temperature capability of the probe station.**

3.2.5 Vacuum Requirements

For the Vacuum Chamber: the probe station vacuum chamber provides thermal insulation for the internal refrigerator as it cryogenically cools the sample being tested. It also prevents condensation or other contamination from affecting the sample.

High quality vacuum equipment is necessary for good cooling performance and for keeping the sample clean. You must provide a vacuum pumping system including appropriate gauges and vacuum lines for the CPX. It must have the ability to attain at least $<10^{-3}$ Torr in the probe station while at room temperature. A vacuum isolation valve with an NW 40 flange is included on the vacuum chamber. Lake Shore offers the PS-V81DP for evacuating the chamber. Components and specifications for these options are in section 2.3.7. You should use these specifications as a guideline if you purchase the pumping system separately.

NOTE **If you do not purchase the turbo pumping system option with the probe station, you will need to provide a calibrated vacuum gauge during installation to verify vacuum levels.**

For Operation Below 4.2 K: a vacuum pump is also necessary when cooling the sample stage below 4.2 K. However, the turbo pumping system recommended for the vacuum chamber is not suitable for this application. Lake Shore offers the PS-LT option for CPX operation down to 2 K. The PS-LT option includes the pump, lines and valves necessary to operate the system safely. Components and specifications for the option are in section 2.3.9. Purchasing the PS-VLT option in addition to the PS-LT extends the base temperature down to 1.5 K. The Lake Shore PS-PLVI-25 pump line vibration isolator or equivalent is recommended when using the PS-LT option.

3.2.6 Gas Requirements

Dewar Pressure: most Dewars will not self pressurize sufficiently to provide the 4.5 liquid L/h maximum cryogen flow rate of the probe station. Room temperature, bottled gas is commonly used to pressurize cryogen Dewars. Typically, helium gas is used to pressurize helium Dewars and nitrogen gas is used to pressurize nitrogen Dewars.

The following must be provided for each cryogen used: a gas cylinder or other source of dry, high purity gas, an independent low pressure regulator capable of providing steady pressure between 13.8 kPa (2 psi) and 69 kPa (10 psi), and gas line and fittings to attach the regulator output to the gas port on the Dewar. Lake Shore does not offer these components as accessories.

WARNING

Gas cylinders must be anchored properly before use. Tipping cylinders can cause serious injury or death.

Vacuum Chamber Purge Gas: during system warm up and sample change operations it can be beneficial to purge the vacuum chamber with inert gas. A purge valve with a ¼ in NPT connection is provided on the vacuum chamber for this purpose. Dry nitrogen gas is recommended for most purge operations, but other inert gasses can be used. Helium is not recommended because it is difficult to pump out when re-evacuating the system.

A regulated nitrogen gas system like the one described in this section under *Dewar pressure* is sufficient for purging the vacuum chamber. It is possible to share one nitrogen gas system between the functions because they are not used at the same time.

Vibration Isolation: Lake Shore offers the PS-PVIS vibration isolation option. You will need to have access to pressurized air to provide steady pressure between 138 kPa and 280 kPa (20 to 40 psi). The connector on the PS-PVIS is a 6.4 mm (¼ in) OD push-to-connect fitting. A 6.4 mm (¼ in) tube 3.7 m (12 ft) long is provided. Lake Shore offers the PA-OAC oil-less compressor option for the vibration isolation system, but it is only available for 120 V line power.

3.3 Unpacking the Probe Station

The following sections describe the unpacking of each component shipped with the probe station. Please report any shortages or potential shipping damage prior to arranging Lake Shore assisted installation or within five days of shipment. It is important that you read and understand this section thoroughly before starting the process. Clear enough space to complete all steps safely.

3.3.1 Shipping Containers

The standard components of the model CPX will be shipped in two crates and one box; one crate contains the probe station itself, the second crate contains the instrument console, and the box contains the cryogen transfer line. Most of the accessories and options configured with the CPX are contained in the crate with the instrument console. The PS-V81-DP and PS-LN2 are two options that are shipped in separate containers. TABLE 3-2 lists approximate size and weight of the standard shipping containers. The weight of the crates varies in the ranges listed below depending on probe station configurations and options ordered.

	Size (l × w × h)	Weight
CPX probe station crate*	1.22 m (48 in) × 0.91 m (36 in) × 1.22 m (48 in)	318 kg (700 lb) to 386 kg (850 lb)
Instrument console and accessories crate*	1.22 m (48 in) × 0.91 m (36 in) × 1.22 m (48 in)	272 kg (600 lb) to 363 kg (800 lb)
Transfer line box	1.63 m (64 in) × 0.76 m (30 in) × 0.13 m (5 in)	8 kg (18 lb)
PS-V81-DP crate (optional)	0.66 m (26 in) × 0.56 m (22 in) × 0.91 m (36 in)	61 kg (135 lb)
PS-LN2 box (optional)	0.56 m (22 in) × 0.56 m (22 in) × 1.04 m (41 in)	48 kg (106 lb)

**Weight may vary depending on configuration and options ordered*

TABLE 3-2 ***Shipping container size and weight***

3.3.2 Inspecting for Shipping Damage

Upon receipt of the system, check for signs of rough handling, such as damage to the shipping container or broken shock indicators attached to the outside and inside of the shipping container. If any physical damage is suspected, do not open containers before photographing the damage and informing the shipping agents and Lake Shore or your local representative. Contact information for Lake Shore service is given in section 6.5. Shipping containers and shipping materials should be kept in the event you would need to return your probe station.

FIGURE 3-3 ***If you suspect damage, take a photo of the packed shipment, specifically damaged areas Left: Probe station; Right: Console and accessories***

3.3.3 Required Tools

The following tools are required to unpack the crated probe station and are not included with the shipment.

- Clean safe work space
- Lifting equipment or four persons capable of lifting at least 22.7 kg (50 lb) each
- Box cutter (knife)
- Phillips head screw driver (battery powered if available)
- Adjustable wrench
- Small diagonal wire cutters

3.3.4 Moving and Lifting the Probe Station

If space and equipment is available, the loaded shipping crates should be moved to the installation site intact. They can be moved easily with a pallate jack while the contents remain protected.

If the CPX must be moved after it is uncrated, it should be strapped to a dock cart for transport.

WARNING

Use lifting equipment or four people, one for each side of the probe station, throughout this procedure. The probe station weighs over 91 kg (200 lb) and is uneven in its weight distribution. Failure to comply may result in injury.

⚠WARNING

The probe station has a high center of gravity and is not mounted to its stand. The probe station should never be moved unless the shipping brackets are in place between the baseplate and the stand

FIGURE 3-4 ***Proper lifting***

3.3.5 Uncrating the System and Stand

These steps will assist you in safely removing the probe station from its crate.

1. Using a Phillips screw driver, remove the screws from the top of the crate containing the probe station.
2. Remove the screws that fasten the wood and foam stabilizer to the long side crate walls. Remove and save the stabilizer.
3. Remove the screws around the perimeter of both short walls of the crate and remove both short walls. Make sure a second person holds onto each of the panels as you remove the screws to make sure the panels do not fall on you or the probe station.
4. Remove both long walls, leaving the wooden cross braces shown in FIGURE 3-3 (left).
5. If there are tie-down straps, remove them. Remove the cardboard surface protectors that protected the baseplate from the tie-down straps.
6. Remove the red shipping brackets that are screwed into the legs of the stand and the crate.
7. Using a utility knife, remove the plastic wrap covering the probe station. To avoid scratching the bellows, begin by cutting the plastic wrap where it covers the vacuum isolation valve (FIGURE 3-5).

FIGURE 3-5 ***Remove the plastic wrap***

8. Lift the probe station off the crate base (see FIGURE 3-4). Use one of the following methods:
   a. Lifting equipment. Screw lifting eyelets into the four ½–13 in threaded holes in the top of the baseplate (FIGURE 3-4). You may need to remove the set screws in the threaded holes before doing this. The lifting eyelets on the instrument console can be removed and used for this purpose.
   b. Four people capable of lifting 23 kg (50 lb) each. Each person should grasp one end of the cross braces as shown in FIGURE 3-4.
9. Move the crate materials out of the work area. It is advisable to save these in the event you need to return the probe station.
10. Move the probe station to its final location.
11. Remove the cross braces from the red shipping brackets.
12. Using an adjustable wrench, take the screws out of the shipping bracket underneath the baseplate.
13. Place your hands underneath the edges of the baseplate and lift up on the baseplate while gently pulling the red shipping bracket down and out. This should be done with four people, a person to lift each side of the station.

3.3.6 Uncrating the Console and Accessories

Use the steps in section 3.3.5 as a guide to uncrate the console and accessories. The number of supports and braces may vary depending on the options and configuration you ordered. Four lifting lugs are provided on top of the console to lift it up and off the crate base. Use the wheels to roll it into its final location. Before moving the console, or moving on in this process, however, be sure to remove the crate and clean the area of any debris left over from the uncrating process.

3.3.7 Unpacking the Probe Station

You will need to unpack the probe station itself, including removing any ties and packing paper. Finally, you will need to unpack the tools, o-rings and hardware.

1. Remove the plastic wrap from the probe station arms and the bayonet.
2. Using wire cutters, cut the plastic ties from the x-axis hand dials. Remove the tape (if any) from the z-axis micrometers.

3.3.8 Unpacking the Instrument Console Crate

Once you have removed the crate from the instrument console, you will need to unpack the various items that were shipped in this crate. Depending on your options, these items may include the vision system, transfer line, turbo pumping system and the accessories box.

3.3.8.1 Unpacking the Instrument Console

The CPX instrument console is a housing cabinet that includes two temperature controllers (Model 340 and Model 332), and the Model 142 power amplifier. All cabling is on the inside of the console. To unpack the console, remove the packaging and prepare the cables for routing. The manuals and additional accessories will be located in the console packaging.

3.3.8.2 Unpacking the Vision System

The vision system is packed in the accessories box next to the console. The microscope components are packed in bubble wrap and boxes. The display is packed in its original packaging. A separate box contains much of the rest of the optics: the light source, microscope, CCD camera and power supply, microscope vertical post and horizontal boom and miscellaneous support items. Unpack these components and set them out in preparation for completing the system setup and assembly.

3.3.8.3 Unpacking the Transfer Line

To unpack the transfer line, cut the bands holding the cover onto the bottom of the long flat box and remove the cover. Cut the plastic ties holding the transfer line in place and lift the transfer line from the box. Remove the protective metal sheath that is taped on, covering the transfer line outlet. The transfer line is best stored by hanging it on hooks on a wall. See FIGURE 3-6 for an image of the transfer line.
The transfer line box also contains the evacuation adapter, which is used to pump out the transfer line yearly or as needed as part of routine maintenance. Do not misplace or inadvertently discard the evacuation adapter shipped with the transfer line. See FIGURE 3-6 for an image of the evacuation adapter.

FIGURE 3-6 ***Left: Transfer line; Right: Evacuation adapter***

3.3.8.4 Unpacking the Turbo Pumping System Option

If you purchased the turbo pumping system from Lake Shore, open the box and remove all plastic wrap and ties. Remove the flexible stainless steel vacuum line from the plastic bag. The NW 40 fittings necessary to connect the turbo pumping system to the probe station will also be included in the instrument console crate. The turbo vacuum system can be left on the floor near the probe station or placed on a cart.

3.3.8.5 Unpacking the Tool Kit and Spares Kit

The tool kit and the spares kit come wrapped in plastic bags in the accessories box. In each kit is a form that lists the included components, part numbers and their use on the probe station. Retain these forms for reference or for use when ordering additional items. The hex keys and lifter tool are needed during assembly and operation. The 8 mm wrench, hardware and o-rings are used for maintenance or configuration changes.

3.3.9 Unpacking the Options

There are various options that you may have purchased with your probe station, and most of these will be packed in the crate with the instrument console.

- *PS-PLVI:* the pump line vibration isolator will be packed in the crate with the console. The bucket will typically not be packed in a box, but will be bubble wrapped and shrink wrapped. The bellows and associated hardware will be bubble wrapped and packed in the accessories box.
- *PS-OAC:* the air compressor is also packed along with the console. It will be packed in a box from its supplier. Please follow supplier directions to unpack it.
- *PS-LN2:* the liquid nitrogen Dewar may be shipped inside the crate with the console, or it may be shipped separately, depending on the options purchased and space available in the crates. It will also be shipped in a box from its supplier. Please follow supplier directions for unpacking it from its box.
- *PS-LT:* the pump portion of the low temperature option is packed alongside the console. It will be bubble wrapped and shrink wrapped. The smaller, associated items will be packed in the accessories box.
- *PS-PVIS:* the pneumatic isolator is integrated into the TMC stand, and it will not be crated separately.

3.4 Assembling a Basic Probe System Configuration

Use the following procedures to complete the assembly process. If a Lake Shore assisted installation was purchased with the system, the installer will begin at this point.

3.4.1 Connecting the Console to the Probe Station

There are three cables with varying numbers of inputs and outputs to attach between the console/power supply and the CPX probe station. It is helpful to attach the cables in the order presented in section 3.4.1.1. The cables are already attached to the back of the controllers and each one is clearly labeled; you will need to complete the connections to the probe station. The information detailed in FIGURE 6-10 will assist you in making the correct connections and for troubleshooting.

3.4.1.1 Complete the Connections to the Probe Station

1. Locate the main temperature control and sensing cable (labeled DC0723). Attach the 19-pin connector to the refrigerator bottom of the vacuum chamber, which has a corresponding 19-pin connection. Note the orientation of the guiding lugs and rotate as necessary. The outer shell should rotate and click into place for a secure connection.
2. Locate the fourth stage cable (labeled DC2048). This is one of three 6-pin connectors that are identical. It will attach to a connection underneath the probe station labeled “fourth stage”.

NOTE

The fourth stage cable and probe arm cable have identical 6-pin feedthroughs on the probe station. If the fourth stage sensor and heater are not reading properly, check that the plugs have not been reversed in error (see section 3.6.2 for a test to check this).

3. Locate the probe arm temperature sensor cable (labeled DC0616) and connect it to the probe arm.

3.4.2 Assembling the Vision System

FIGURE 3-7 illustrates the assembly of a single-post microscope, CCD camera and ring light. The vertical post, horizontal boom, microscope and CCD camera are connected to the CPX baseplate. The position of the shaft collar determines the height of the microscope above the sample, and may require adjustment after assembly of the vision system.

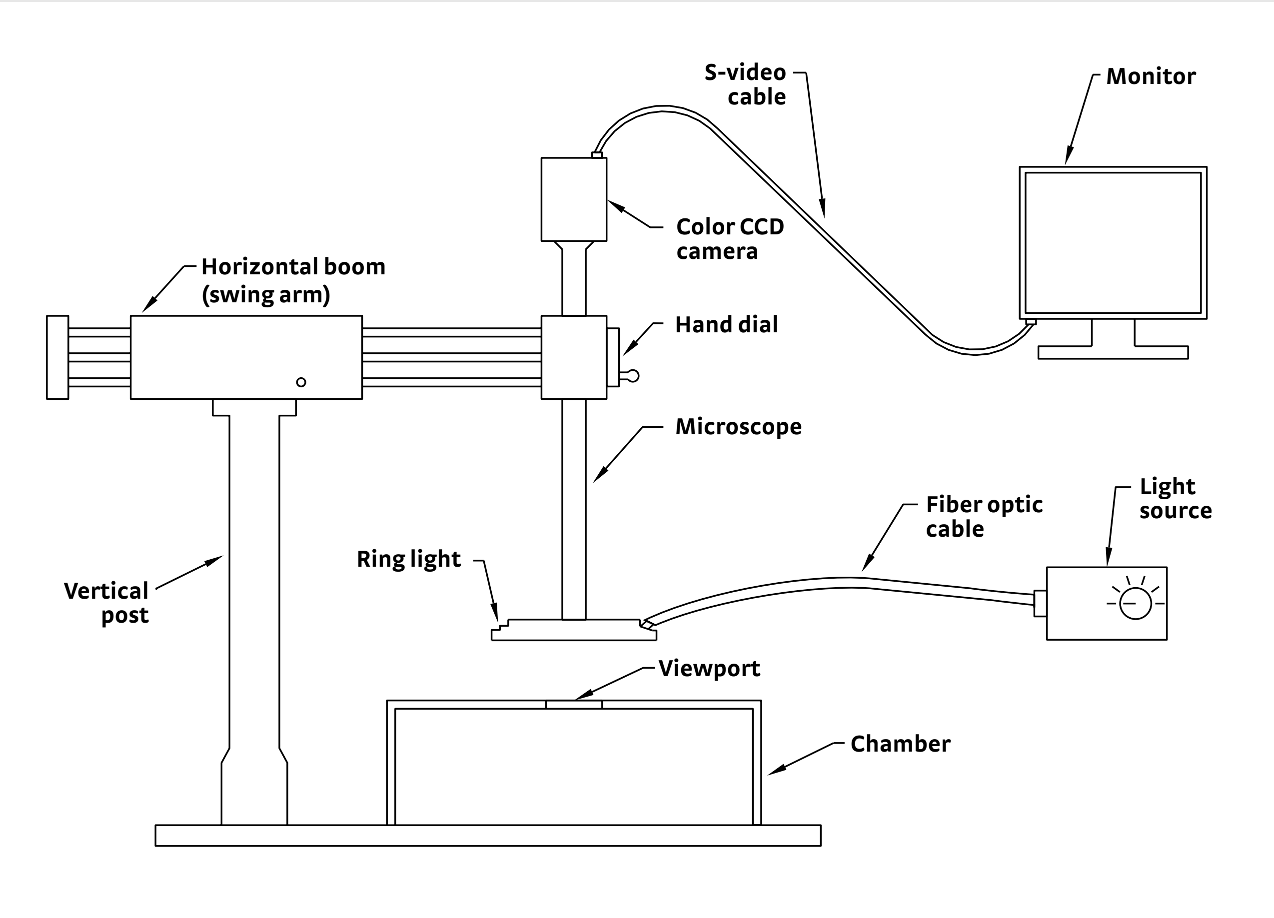


FIGURE 3-7 ***Assembly of the vision system onto the probe station***

3.4.2.1 Assemble the Vertical Post

Follow this procedure to install the vertical post onto the baseplate. Depending on the microscope option and probe station model, the microscope post will have either one or two shafts. The Zoom 70 has one shaft and the Zoom 160 has two.

1. Install the microscope vertical post as shown in FIGURE 3-8. To install the post, remove the one or two M5 screws in the bottom of the post.
2. Align the post so that one of the two screw holes on the vertical post mount is over the hole that is closest to the vacuum chamber. The other screw hole will align with the third hole further away from the vacuum chamber.
3. Place the two M5 screws in their respective holes and finger tighten each one.
4. Using the 5 mm hex driver, tighten each one until secure.

3.4.2.2 Assemble the Microscope and Horizontal Boom

1. Using the 3 mm hex driver, remove the four M3 mounting screws (FIGURE 3-8) from the microscope.
2. Attach the microscope to the horizontal boom (see FIGURE 3-8) with the screws that were removed in step 1. The microscope attaches beside the hand dial.

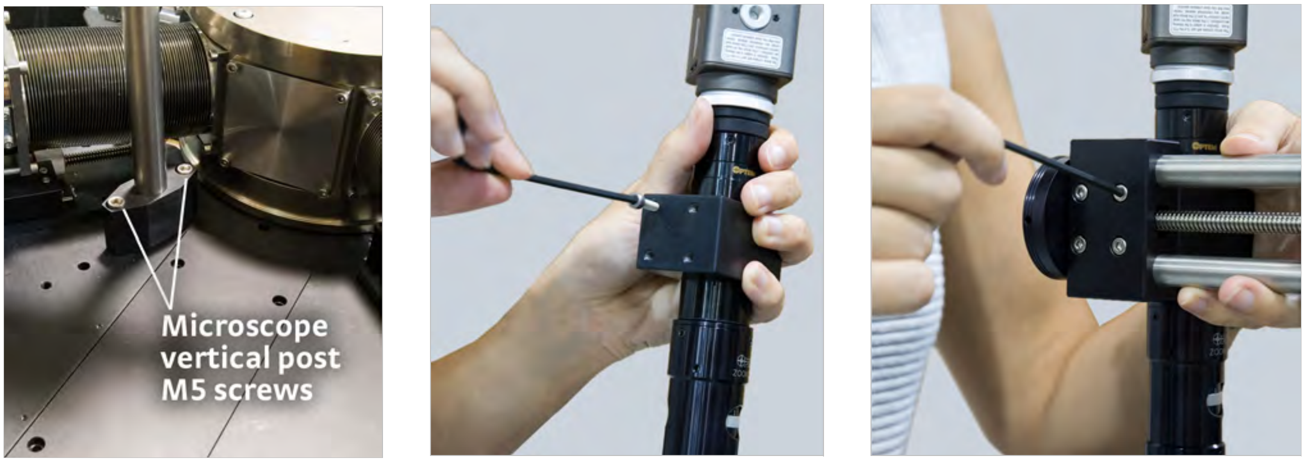


FIGURE 3-8 ***Left: Installing the microscope vertical post; Middle: Four M3 mounting screws on the vertical post; Right: Attaching the microscope to the horizontal boom***

3. Slide the horizontal boom onto the vertical post as shown in FIGURE 3-9. You may need to turn the white plastic nut counterclockwise to allow it to slide easily. If the microscope physically touches the vacuum chamber lid, adjust the shaft collar before moving on; section 6.3.4.5 describes how to adjust the shaft collar.

FIGURE 3-9 ***Installing the horizontal boom onto the vertical post***

3.4.2.3 Connect the Vision System

1. Connect the microscope electronics. These consist of two parts:
   a. The 12 V DC power supply connects to the plug on top of the microscope.
   b. S-video cable: connect one end to the top of the microscope as well. It will align in only one direction for the connection (FIGURE 3-10). Attach the other end of this cable into the s-video connection on the monitor.
2. Attach the monitor power supply to the monitor. This is a 12 V DC connection.

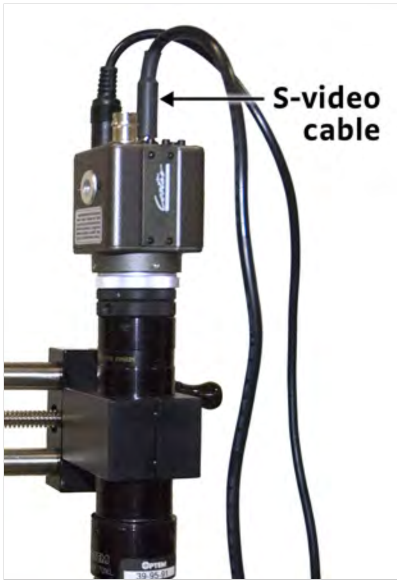


FIGURE 3-10 ***Attach the s-video cable to the microscope***

3. Connect the fiber optic. The steps vary depending on whether you are using the ring light or the coaxial light.

   Ring Light:
   a. Screw the light source adapter onto the bottom of the microscope, using the three screws supplied (FIGURE 3-11). Finger tighten only.
   b. Insert the fiber optic cable into the light source. Finger tighten only (FIGURE 3-11).
   c. Connect the power cord to the light source (see TABLE 3-1 for power requirements).

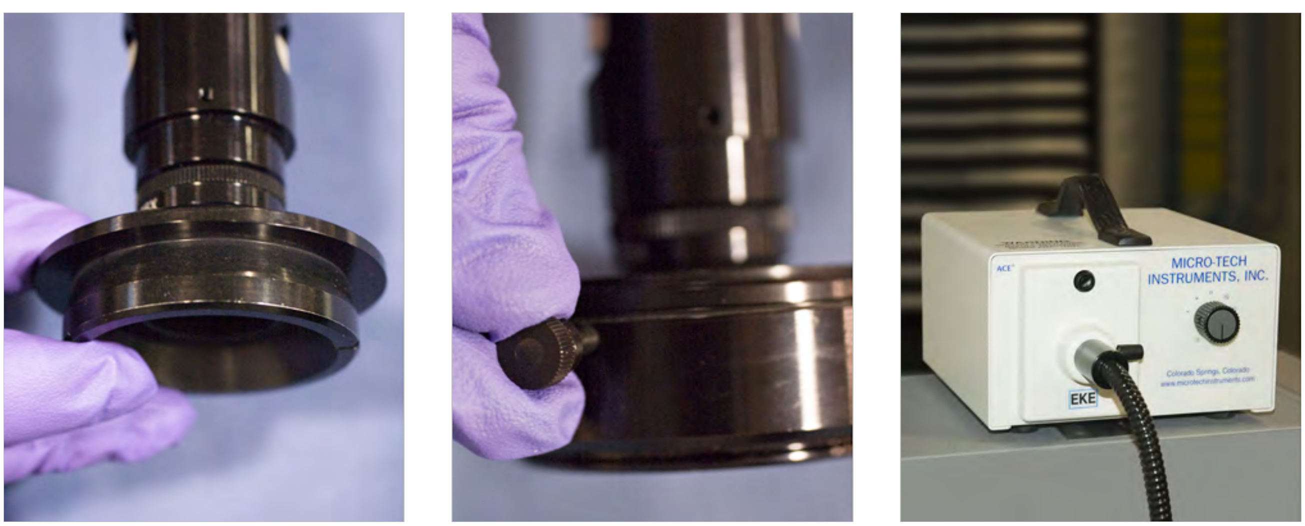


FIGURE 3-11 ***Left: Installing the ring light onto the adapter; Middle: Tighten the ring light thumbscrews; Right: Fiber optic cable attached to the light source***

Coaxial Light:

a. Using the 0.05 in hex driver, loosen the set screw on the fiber optic cable fitting to the microscope (FIGURE 3-12).
b. Remove the protective metal fitting.
c. Insert the fiber optic cable.
d. Secure the set screw.
e. Insert the fiber optic cable into the light source. Finger tighten only.
f. Connect the power cord to the light source (TABLE 3-1).

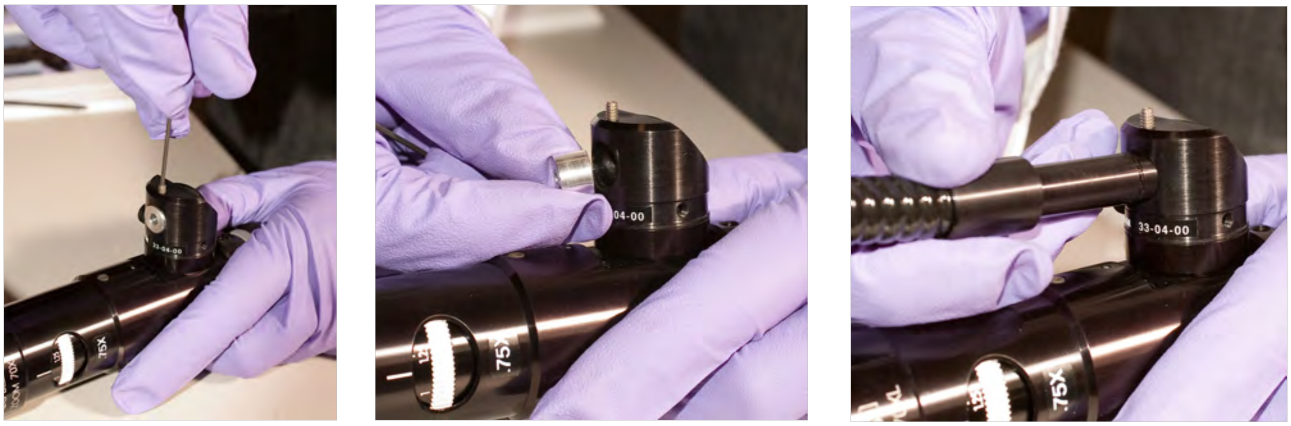


FIGURE 3-12 ***Left: Loosen the set screw on the fiber optic cable fitting; Middle: Remove protective fitting; Right: Insert the fiber optic cable***

3.4.3 Assembling the Turbo Pumping System

Before assembling the turbo vacuum pump with the probe station, it is a good idea to test the turbo vacuum pump alone (section 6.3.1.1). FIGURE 3-13 shows the assembled turbo pumping system and the connections of the turbo pumping system components. Most of these components have already been assembled.

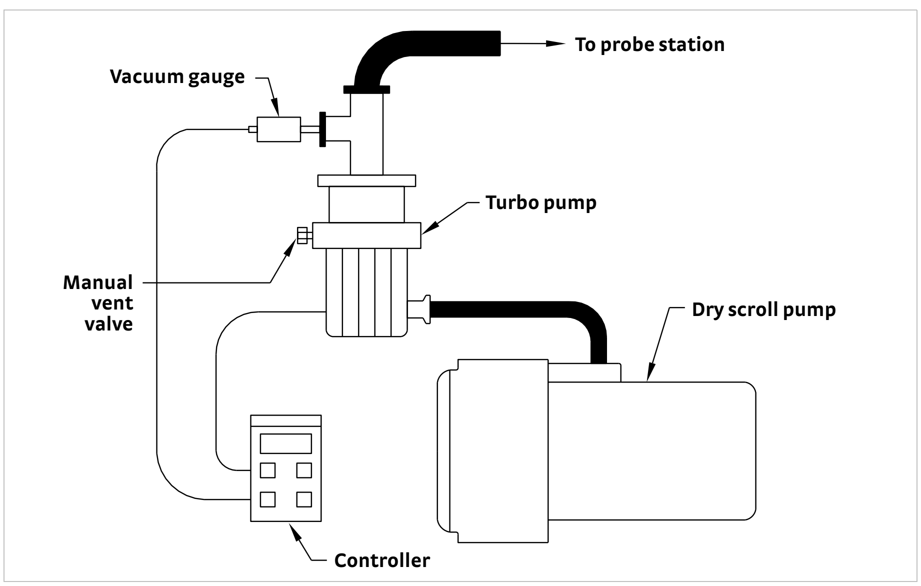


FIGURE 3-13 ***Assembled turbo pumping system and its connections***

3.4.3.1 Prepare the Probe Station Before Attaching the Vacuum

The probe station is shipped under vaccum; you need to release this vacuum. Follow this procedure to release the vacuum.

1. Attach a dry nitrogen or inert gas line to the purge valve. We recommend you purge to dry nitrogen instead of purging to air in order to increase and maintain the pumping efficiency of the system.
2. Regulate the gas pressure to 6.89 kPa to 13.79 kPa (1 to 2 psi).
3. Open the purge valve slowly. In about one minute, the pressure relief valve on the chamber will open and release gas.
4. Close the purge valve completely.
5. The gas line can be left in place or removed.

3.4.3.2 Prepare the Turbo Vacuum Pump Components

If you purchased the turbo pump specified by Lake Shore, follow this procedure to prepare it.

1. If the vacuum gauge (FIGURE 3-14) is not already installed on top of the turbo vacuum pump, remove the protective caps. Then use the provided clamp and center ring to attach the gauge.
2. Remove the blank off plate from the connector on top the vacuum gauge. Attach the supplied cable to this connector (see FIGURE 3-14). If not already done, attach the other end of the cable to the connector on the back of the gauge controller (FIGURE 3-14).

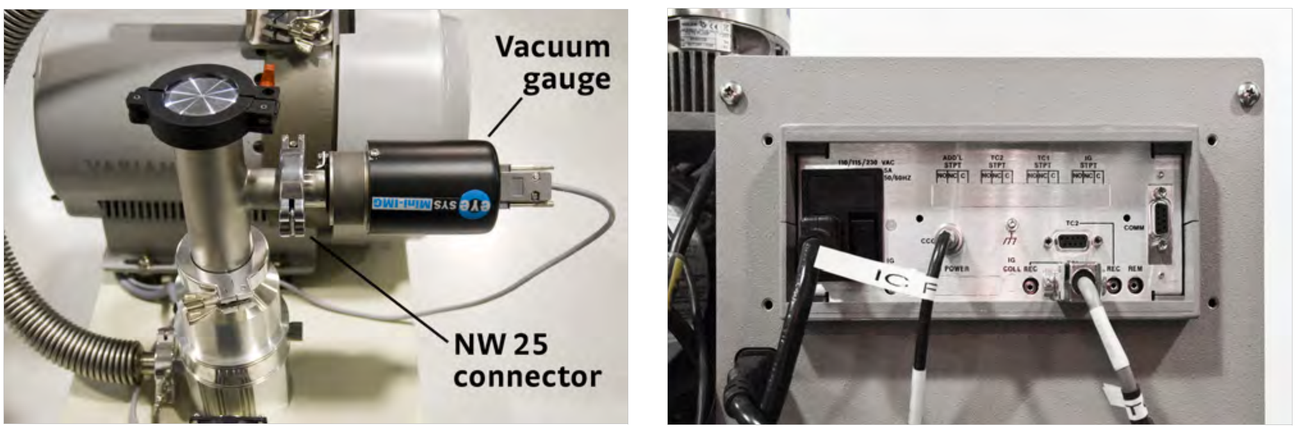


FIGURE 3-14 ***Left: Vacuum gauge; Right: Back panel of the gauge controller***

3. Attach the NW 40 flanges of the vacuum line to the T on the pump.
    a. Remove the clamp and protective cap from the fitting shown in FIGURE 3-15. The center ring may come out; retain the ring to use in the next step.
    b. Holding the center ring in place, set the vacuum line against the ring.
    c. Close the clamp around the fitting.
    d. Finger tighten the clamp with the screw. See FIGURE 3-15.

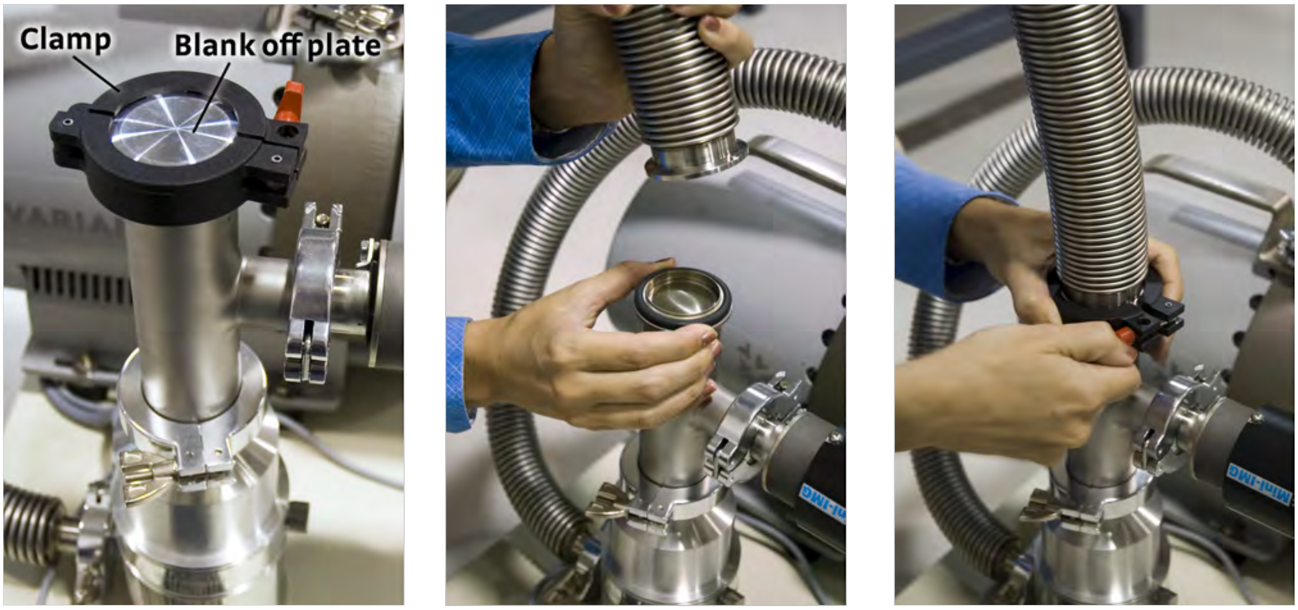


FIGURE 3-15 ***Left: Remove the clamp and protective cap; Middle and Right: Install the vacuum line to the pump***

4. Remove the blank off plate from the NW 40 vacuum isolation valve. The clamp and centering ring are used when the vacuum hose is attached in the next step.
5. Attach the other end of the vacuum line to the vacuum isolation valve on the probe station (FIGURE 3-16).

FIGURE 3-16 ***Use the clamp provided to attach the vacuum line to the probe station***

NOTE **To minimize the transfer of vibration to the probe station, position the turbo pumping system so that the vacuum line has at least one 90° bend in it.**

NOTE **Do not remove or exchange the plastic clamp and centering ring installed between the isolation valve and the vacuum chamber. These electrically isolate the chamber from the turbo pumping system. This eliminates most of the electrical noise that might otherwise be coupled from the turbo pumping system to the probe station, and also eliminates a potential ground loop in the system.**

6. Connect the power cord to the turbo pumping system (see TABLE 3-1).

3.4.4 Assembling Probe Station Options

Some options require some assembly, while others come fully assembled. This section explains how to assemble the options and attach them to the probe station.

3.4.4.1 Assembling the Pump Line Vibration Isolator (PS-PLVI-40 or PS-PLVI-25)

The PS-PLVI-40 is for the PS-V81DP turbo pumping system. The PS-PLVI-25 is for the PS-LT low temperature option. The pump line vibration isolator includes a bucket with NW 40 or NW 25 fittings and 1 m flexible stainless steel vacuum line. The bucket must be filled with pre-mix concrete to provide the vibration isolation. This requires approximately 40 kg (90 lb) of concrete (not included).

1. Mix the concrete according to directions provided with the concrete.
2. Fill the bucket with the mixture.
3. After the concrete has cured, turn the bucket handle-side up and place it on the three rubber pads included with the kit (FIGURE 3-17).
4. For the PS-PLVI-40, connect the bucket between the turbo pumping system and the probe station's vacuum isolation valve.
5. For the PS-PLVI-25, when directed, connect the bucket between the PS-LT rotary vane pump and the probe station.

FIGURE 3-17 ***Pump line vibration isolator***

3.4.4.2 Assembling the Low Temperature Option (PS-LT)

The low temperature option consists of a rotary vane pump, dual valve assembly, fittings, flexible stainless steel vacuum line and an oil exhaust filter with an oil return line. Follow this procedure to assemble the exhaust filter with oil return line to the rotary vane pump.

1. Remove the centrally located screw from the pump side of the oil exhaust filter.
2. Remove the elbow fitting with the orange push-to-connect fitting from the end of the oil return tube.
3. Attach the elbow fitting to the centrally located tapped hole in the pump side of the oil exhaust filter. You will need to hold the fitting stationary; then use a 9 mm wrench to rotate the nut until the fitting is secure.
4. Remove the gas ballast plug and screw the return line fitting into the gas ballast. Screw it in firmly, but do not overtighten.
5. Secure the oil exhaust filter to the “out” exhaust using the NW 25 clamp.
6. Fit the oil return tube into the orange push-to-connect fitting on the oil exhaust filter. Attach the other end to the orange push-to-connect fitting on the return line fitting. For the push-to-connect fitting, be sure to push in, pull out and then push in again to ensure a secure fit.

3.4.4.3 Assembling the Pneumatic Vibration Isolator (PS-PVIS)

The pneumatic isolator is integrated into the TMC stand. To assemble the isolator, fit the ¼ in OD compressed air tube into the red push-to-connect fitting on the isolator. Flow 172 kPa to 241 kPa (25 to 35 psi) compressed air into the stand. Consult the TMC manual for further instruction.

3.4.4.4 Assembling the Oil-less Air Compressor (PS-OAC)

The air compressor comes fully assembled and simply needs to be plugged in (see TABLE 3-1 for power requirements). The air compressor line will be attached to the red push-to-connect fitting under the table when you are ready to level the TMC table.

3.4.4.5 Assembling the Liquid Nitrogen Dewar (PS-LN2)

The PS-LN2 liquid nitrogen Dewar option is packed in a cardboard box and included in one of the larger shipping crates. Parts included with the option come fully assembled. Several items necessary for operation and not included with the option must be assembled prior to use.

- The compression fitting for the withdraw leg of the transfer line is included with the spares kit and must be located and threaded to the top withdraw port of the Dewar.
- Dry nitrogen gas is required to pressurize the Dewar during operation. A regulated source of dry nitrogen must be adapted to the vent port on the PS-LN2. The vent port comes with a ³⁄₈ in NPT fitting. An easily removable (quick connect) fitting is recommended because the line may need to be removed to fill the Dewar.
- A temporary nitrogen fill line must also be available to transfer LN_2 from a larger storage Dewar or building source into the liquid port on the PS-LN_2. The transfer line included witht the probe station is not suitable for this purpose. The liquid port comes with a ³⁄₈ in flair fitting, which is compatible with many flexible LN2 transfer lines available in the United States. The fitting can be removed if it is more convenient to adapt to the ³⁄₈ in NPT valve.

3.4.4.6 Assembling the Dewar Pressure Controller (PS-DPC)

The Dewar pressure controller comes fully assembled. Follow this procedure to complete the setup.

1. Hang the Dewar pressure controller on the Dewar.
2. Plug it into the power source.
3. Attach a 6 mm (¹⁄₄ in) tube into the green push-to-connect fitting on the inlet in the Dewar pressure controller.
4. Attach the other end of this tube to your gaseous helium or nitrogen source capable of 68.9 kPa (10 psi).
5. Connect the outlet to the vent port on the Dewar.
6. Consult the pressure controller manual for further information.

3.5 Installing and Removing Probes

Probes are installed at the ends of probe arms, inside the chamber. The chamber and radiation shield must be opened. It may also be helpful to remove the sample holder to make more room to work inside the chamber.

CAUTION

The probes are packaged separately to protect the delicate tips. Do not touch the tips. Do not handle the alumina blade or the electrical conductors on the ZN50 probe with bare hands, as this may reduce its isolation. Wear nitrile gloves while changing blades.

3.5.1 Probe Anchoring and Probe Temperature

In the CPX probe station, the probe mount braids can be anchored to either the sample stage or the 4 K radiation shield stage (FIGURE 3-20). The decision for which location to use can be made based on the specific application. Thermally anchoring to the 4 K stage maintains the probes near the temperature of the 4 K shield stage, while anchoring to the sample stage allows the probes to change with the sample temperature. For most applications a probe cooled to or below the sample

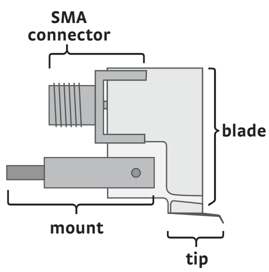
temperature is desired. Therefore we recommend thermally anchoring the probe mount braids to the 4 K shield stage so that the thermal mass of the probes and probe arms will be cooled initially and remain cold when changing sample stage temperature. This will allow the sample stage to change and stabilize in temperature more quickly. Thus, the default location for mounting is to the 4 K shield.

3.5.2 Installing a Probe: Prep Instructions for All Probe Types

Follow this procedure to prepare for installation of all probe types, then use the unique instructions for each individual probe type.

1. Open the vacuum chamber and radiation shield using the guidelines in section 4.3.1 .
2. If you purchased semirigid cables or coaxial cables, there will be safety ties on the arms. Cut these off, and remove the ties from all four cables. Be careful not to cut the Kapton® tape on the coaxial cables. You may need to use the x-axis hand dial to move the probe arms in or out so that the ties are more accessible.
3. Using the x-axis hand dial, extend the probe arm into the chamber until the probe arm set screws are accessible.

3.5.3 Installing a ZN50 Probe



The ZN50 series probes consist of a probe mount, ceramic blade with SMA electrical connector and probe tip. Use the procedure in section 3.5.3.1 to install a ZN50 probe. If the probe mounts are already installed (see FIGURE 3-18), go to section 3.5.3.2 and begin with installing the probe blade. If the probe mount is not installed, please be aware that some probe station users find it easier to first install the blade to the probe mount outside the station (section 3.5.3.2), and then install the probe to the probe arm.

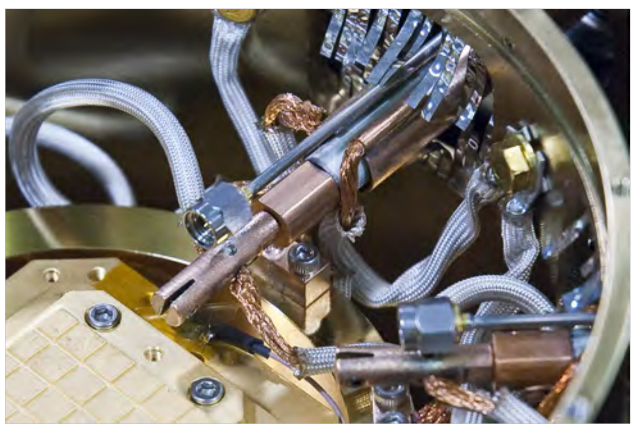


FIGURE 3-18 ***CPX with probe mount installed***

3.5.3.1 Install the ZN50 Probe Mount

1. Follow the procedure in section 3.5.2.
2. Flex the probe mount braids so that the copper braid block will be in approximately the correct position for attachment (FIGURE 3-19).
3. If desired, apply a small amount of Apiezon® N brand grease to the end of the dowel and the bottom of the braid block (FIGURE 3-19). The grease enhances the thermal contact between the probe and the probe arm; however, some users prefer to keep the sample area free of all greases. Specified system performance does not require grease on the bottom of the probe arm braid block or on the probe dowel.

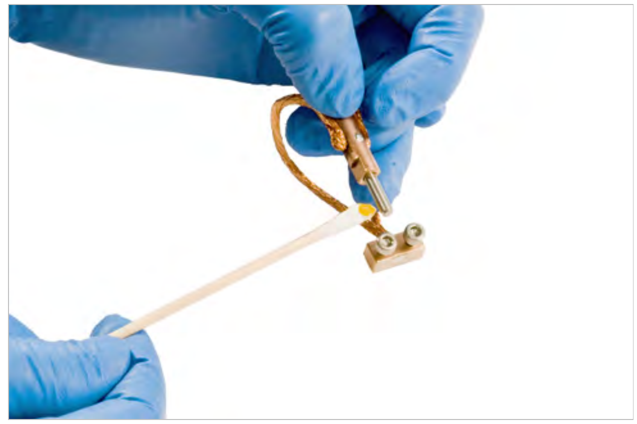



FIGURE 3-19 ***Left: To install the probe mount, bend the probe mount braids; Right; Apply grease to the end of the dowel***

4. Slide the dowel of the probe mount into the end of the probe arm and, using the 1.5 mm hex driver, tighten the set screws that hold the probe mount in place.
5. Attach the braid block. The braid block is used as a thermal connection between the probe tip and the anchor location. Use this procedure to attach the braid block to the 4 K shield before installing the probe tip to minimize the chance of accidentally hitting the probe tip.
   a. Using the x-axis hand dial and y-axis micrometer, move the probe arm to expose the braid block mounting holes in the 4 K shield stage (FIGURE 3-20).
   b. Position the braid block over the holes in the 4 K shield stage using tweezers.
   c. Using the 2.5 mm hex driver, attach the braid block to the 4 K shield stage with the two M3 captive screws (see FIGURE 3-20 for an image of the mounted braid block).

NOTE

The probe mount braids can touch neighboring probe braids or the stage it is anchored to, but should not touch adjacent stages. In the CPX probe station, the probe mount braids can be anchored to either the sample stage or the 4 K radiation shield stage (FIGURE 3-20).

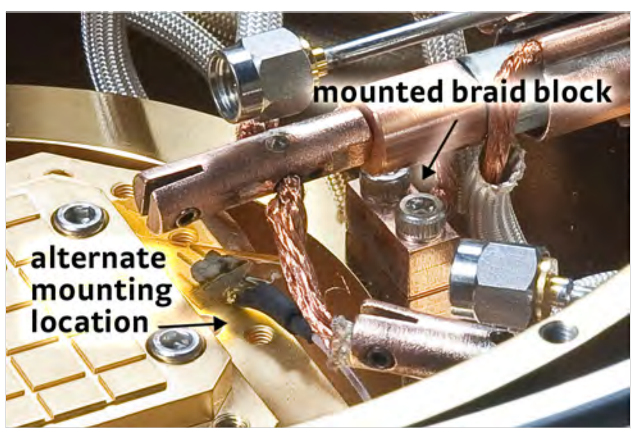


FIGURE 3-20 ***Braid block mounting holes***

3.5.3.2 Install the ZN50 Probe Blade

Follow this procedure to install the blade inside the probe station. You may find it easier to install your blade outside of the probe station; to do this you will need to remove the probe mount (section 3.5.4.2) and follow the procedures in step 3.

1. Using the 1.5 mm hex driver, loosen the set screws on the probe arm so that the probe mount can rotate freely (FIGURE 3-21).

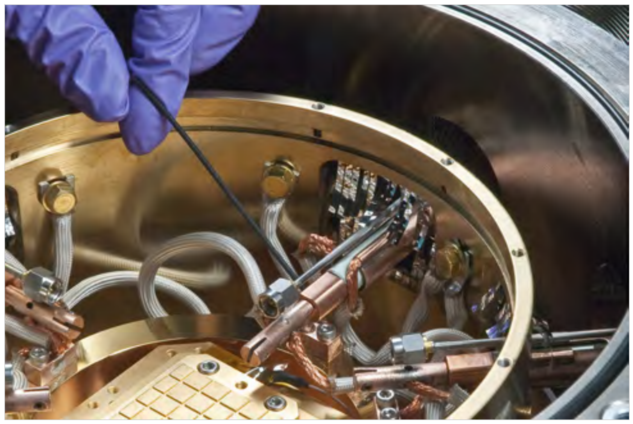


FIGURE 3-21 ***Loosen the probe arm set screws***

2. Rotate the mount so that you have access to the mount set screw.
3. Insert the blade:

    a. Verify that the mount set screws are out far enough that the blade can slide in easily. If they are not, unscrew them slightly to accommodate the blade.

    b. Slide the new blade all the way into the probe slot (FIGURE 3-22). Its bottom edge should be square and flush with the bottom of the probe mount . Hold the new blade in position.

NOTE

Positioning the blade so its bottom is flush with the bottom of the probe mount ensures that the SMA connector will not contact the probe mount. During operation, the body of the SMA connector may have a different voltage potential on it than the probe mount and, therefore, it should not touch the probe mount.

    c. Using the 1.5 mm hex driver, start the set screw, and once the probe is secure, tighten it just until you feel it touch the blade.

CAUTION

It is important that you do not overtighten the screw, as you could crack the probe blade.

    d. Rotate the probe mount and tighten the opposing set screw, keeping the blade all the way back in its slot and flush to the probe mount (FIGURE 3-22). Tighten the screw until the blade does not move with finger pressure. Be careful not to over-tighten, as the alumina is delicate and will crack. Rotate the probe back to the upright position.

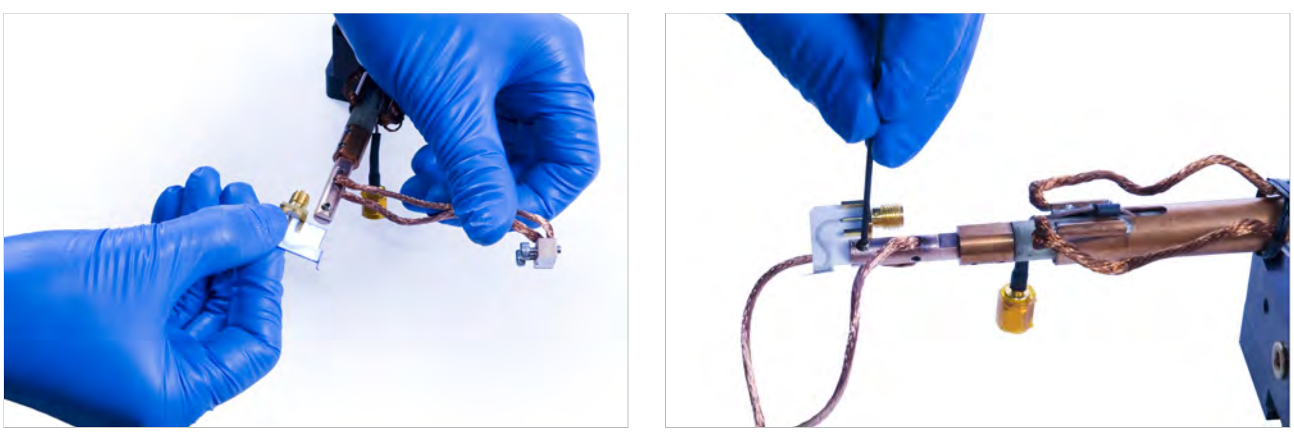


FIGURE 3-22 ***Left: Slide the blade into its slot; Right: Carefully tighten the probe mount set screws***

4. Using the 1.5 mm hex driver, secure the probe to the probe arm by tightening the probe arm set screws.
5. Finger tighten the signal cable SMA nut onto the probe's SMA connector.

CAUTION

For the cryogenic coaxial cable, the strain relief to the SMA connector must be held steady with tweezers while the plug is screwed onto the probe's SMA socket, otherwise the cable's center conductor can be broken. Hand tighten until snug.

NOTE

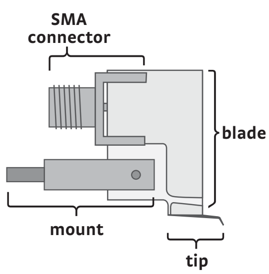
If installing the ZN50 probes on arms configured with K-connectors and semirigid coaxial cable, refer to section 3.5.5, steps 5 to 8 for proper alignment of the connector.

6. Before initiating a cryogen transfer, see section 3.6.4 and section 3.6.5 to test probe arm reach and landing ability. It would be very costly and time consuming to initiate a cooldown only to find that a probe mount braid is preventing the probes from landing.

NOTE

Do not remove the tape covering the SMA plug on the cryogenic coaxial cable. The tape prevents contact with the radiation shield curtains (the flexible aluminized strips covering the openings) or other conductive elements in the sample area, which would short the guard signal to ground.

3.5.4 Removing a ZN50 Probe



The ZN50 series probes consist of a probe mount, ceramic blade with SMA electrical connector and probe tip. You can simply remove the alumina probe blade on ZN50 probes if it has been damaged or if a different tip is desired. You will need to remove the probe mount if you are installing a different kind of probe than was previously installed.

3.5.4.1 Removing the ZN50 Probe Blade

You can remove the probe blade in the probe station or out of the probe station. These steps describe removing the blade while it is in the station. If you wish to remove the blade from its mount outside of the probe station, first remove the probe mount (section 3.5.4.2) and then follow steps 5–8 in this section.

1. Follow the procedure in section 3.5.2.
2. Disconnect the SMA connector. The strain relief to the SMA connector (on the cryogenic coaxial cable) must be held in place with tweezers or your fingers while removing the SMA plug (FIGURE 3-23).

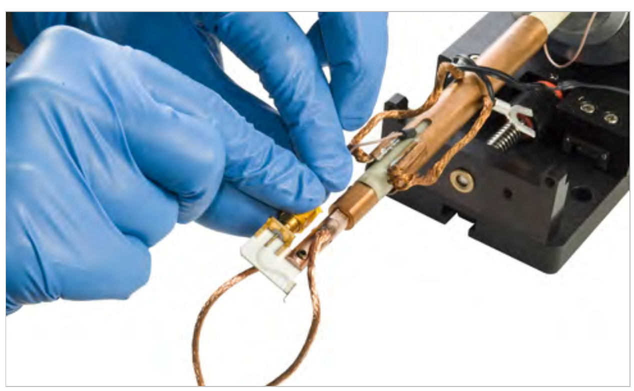


FIGURE 3-23 ***Disconnect the SMA***

NOTE

You only need to loosen the screws in steps 3–5. Do not remove them. This will keep them from dropping into the chamber.

3. Using the 1.5 mm hex driver, loosen both of the M3 probe arm set screws two to three turns (FIGURE 3-24) to rotate the probe to access one of the probe mount set screws.

FIGURE 3-24 ***Loosen the probe arm set screws***

4. Using the 1.5 mm hex driver, loosen the visible probe mount set screw (FIGURE 3-25).
5. Rotate the probe mount to access the set screw on the other side of the probe mount and loosen that screw as well.
6. Gently work the blade up and down to release and remove it. Avoid sideways force to minimize the chance of cracking the alumina.
7. Remove the blade from the system and place it back into its storage case, making sure not to contact the delicate probe tip.

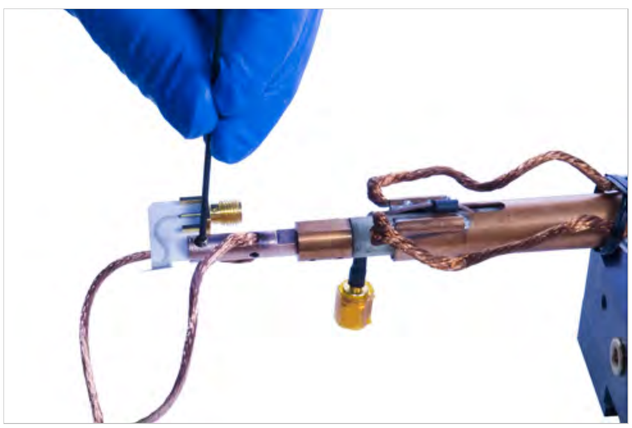


FIGURE 3-25 ***Loosening the probe mount set screws***

3.5.4.2 Removing the ZN50 Probe Mount

1. If you have not yet removed the blade, you will need to disconnect the SMA connector. The strain relief to the SMA connector (on the cryogenic coaxial cable) must be held in place with tweezers while removing the SMA plug.
2. Using the x-axis hand dial and the y-axis micrometer, move the probe arm to expose the braid block mounting holes in the 4 K shield stage.
3. Using the 2.5 mm hex driver, loosen the two captive screws on the braid block (FIGURE 3-20).
4. Pull the braid block out.
5. Using the 1.5 mm hex driver, loosen both M3 probe arm set screws two to three turns and slide the dowel out of the probe arm (FIGURE 3-21).
6. Pull the probe mount out of the probe station.

3.5.5 Installing a Microwave Probe

The K-connector, 2.4 mm connector and the V-connector all look very similar; however, they may not mate to a connector of different frequency rating and the probe or cable may be damaged if forced to thread to an improper mate. See section 2.5.1 for more information. Contact Lake Shore if you are still unsure of your probe station's microwave configuration.

Unlike the ZN50 blade and optical fiber assemblies that use a separate probe mount, the microwave probe has an integrated mount that attaches to the probe arm, and includes probe mount braids and a braid block for attachment to the thermal anchor point.

CAUTION

GSG microwave probe tips are extremely delicate; the slightest touch on the probe tips can disturb the ground-signal-ground (GSG) transmission line geometry, thereby degrading performance. Due to the high cost of replacement microwave probes, we highly recommend that users become comfortable with probing techniques using ZN50 probes prior to installing and probing with microwave probes to avoid damage to the microwave probe tips (Lake Shore provides two ZN50-25-BECU and two ZN50-25-W probe tips in the spares kit).

Follow this procedure to install a microwave probe. If a ZN50 or optical fiber probe mount is installed in your probe station, you will need to remove it first (section 3.5.4.2 or section 5.3.7.1).

1. Follow steps 1–4 in section 3.5.2.
2. Remove a microwave probe from its storage case.
3. Grasp the microwave probe between thumb and forefinger on the sides of the probe body so that the dowel is extending outward from your hand and the braid block is dangling below your hand (FIGURE 3-26).

FIGURE 3-26 ***Proper handling of a microwave probe***

4. Using the 1.5 mm hex driver, loosen the set screws on the probe arm and slide the dowel of the microwave probe into the probe arm (FIGURE 3-21).
5. As you slide the microwave dowel onto the probe arm, note the relative height of the microwave connector socket on the probe and the microwave connector plug on the semirigid cable. If the relative heights of the two connectors do not match, the semirigid cable can be gently bent using the thumb and forefinger to align the connector plug with the height of the connector socket (FIGURE 3-27).

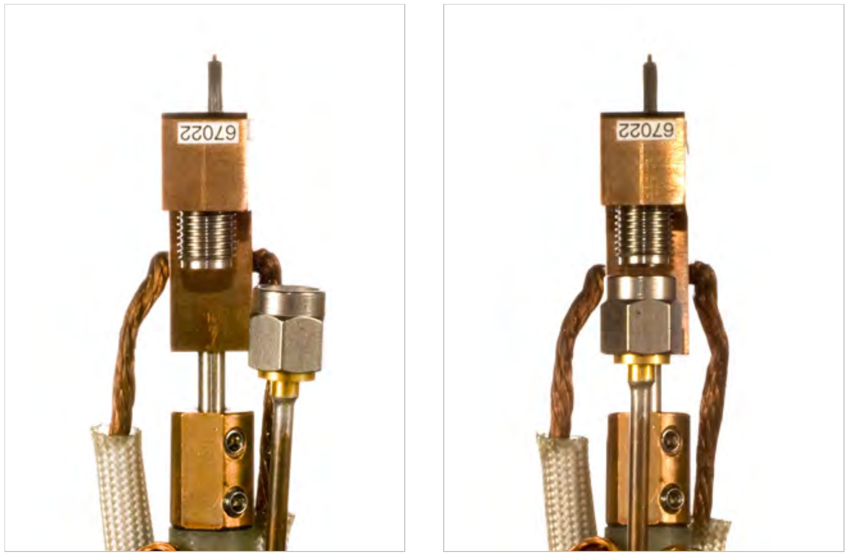


FIGURE 3-27 ***Left: Misaligned probe; Right: A properly aligned probe***

6. Continue to slide the microwave dowel onto the probe arm until the microwave connector socket aligns with and contacts the connector plug on the semirigid cable. The semirigid cable can be gently lifted or pushed to one side or the other to help align the two connectors.
7. Carefully start threading the connector plug onto the probe connector socket. The probe can be rotated slightly to better align it as you thread. Refer to section 5.3.6.3 if the cable length seems inappropriate.
8. If the connector is properly aligned, it will make good contact simply by finger tightening. It is acceptable if the back of the copper probe body is not flush with the copper end of the probe arm

NOTE **A wrench should not be used to tighten the plug onto the microwave probe unless it is a calibrated torque wrench specifically designed for making microwave connections.**

FIGURE 3-28 ***Microwave probe threaded onto a semirigid cable***

9. Once the microwave connector is tight, use the 1.5 mm hex driver to tighten both probe arm set screws. If the probe body was rotated in order to ease the alignment of the microwave connectors when threading, hold the microwave probe body with your thumb and forefinger as you tighten the set screws to vertically align the probe.

10. Attach the braid block using these steps:
    a. Use the x, y and z-axis micrometer controls to position the probe so that the braid block can be attached without disturbing the probe tips.
    b. Using tweezers or your fingers, position the braid block over the mounting holes (FIGURE 3-20).
    c. Using the 2.5 mm hex driver, attach the thermal braid block to the chosen location on either the sample stage or the 4 K shield stage, very carefully, so as not to contact the delicate probe tips.
11. Before initiating a cryogen transfer, see section 3.6.4 and section 3.6.5 to test probe arm reach and landing ability, and see section 4.6.4 to planarize the microwave probe. It would be very costly and time consuming to initiate a cooldown only to find that a probe mount braid is preventing the probes from landing.

3.5.6 Removing a Microwave Probe

Follow this procedure to remove a microwave probe from the probe arm.

1. Detach the braid block using these steps:
    a. Use the x, y and z-axis micrometer controls to position the probe so that the braid block can be removed without disturbing the probe tips.
    b. Using the 2.5 mm hex driver, loosen the two captive screws on the braid block until it is free. Detach the thermal braid block very carefully, so as not to contact the delicate probe tips.
2. Using the 1.5 mm hex driver, loosen both M3 probe arm set screws two to three turns.
3. Carefully loosen the connector plug from the probe connector socket.
4. Grasp the microwave probe between thumb and forefinger on the sides of the probe body.
5. Slide the microwave probe off the probe arm.
6. Replace the microwave probe back into its storage case.

CAUTION

Microwave probes should always be returned to the storage case with the foam block holding down the flexible probe mount braids to prevent the braids from coming forward and contacting the delicate tips.

3.6 System Verification and Testing

This section describes a sequence of short tests that can be used to verify that the probe station has been assembled correctly and is in good working order. These tests should be done after making changes to the probe station configuration but before cooling down the system. The goal is to find small problems before investing the time and resources into cooling the system.

These procedures assume that the station has been fully assembled as described in section 3.4.

3.6.1 Console Verification

The instrument console is a housing cabinet that includes two temperature controllers (Model 340 and Model 332), and the Model 142 linear amplifier.

3.6.1.1 Verifying Voltages

The console is shipped from Lake Shore with user specified line voltage selected. If the system is being moved, or there is any reason to believe the voltage may not be appropriate for the installation site, please verify line voltage settings. The Model 332 and the Model 340 both have a voltage selection with the same design fuse casing. From the back of the console, look at the voltage selection window to find the voltage setting. If you find you need to change the voltage, contact Lake Shore for assistance. You can find contact information in section 6.5.

3.6.1.2 Verify Power On

All controllers are plugged into the power strip inside the console. First plug in the power strip (see TABLE 3-1 for power requirements); then, verify that all the power on switches in the back of the controllers are in the on position. On the front right hand side of the console, you will find a rocker switch. This is the main power switch. For some consoles, turning this on will automatically trigger the power to the Model 142 linear amplifier; for others, you may have to physically press the switch on the linear amplifier.

3.6.1.3 Verifying the Model 332 and Model 340 Controllers

The control settings for the Model 332 and 340 are set at Lake Shore; however, it is good to verify them for safety purposes and to acquaint yourself with the controllers. You can use TABLE 4-1 and TABLE 4-2 in section 4.5.7 to assist you in verifying or resetting them. You can find more information on the controllers in their manuals.

3.6.2 Temperature Sensor and Heater Test

Each of the four refrigerator stages in the CPX (sample, 4 K shield, radiation shield and second shield) has a temperature sensor and heater. Prior to heating or cooling the system it is important to verify that the sensor, heater, cabling and temperature controller are all configured properly. If any of the control loop wiring is mixed up or a sensor is malfunctioning, it is possible for the system to overheat and become damaged during warm up. You can check the instrumentation wiring diagram if your probe station does not perform as these tests suggest.

Use steps 1–4 to prepare the system for the sensor and heater test. Then use TABLE 3-3 to run the sensor and heater test.

1. With the system stabilized at room temperature, verify that all sensors read within a few degrees of each other. Only the sensors on the sample stage and 4 K shield stage are accurately calibrated, so some discrepancy in the readings can be expected.
2. Install the radiation shield lid and vacuum chamber lid.
3. Use the z-axis micrometers to raise all probes up 3 mm to 4 mm above the sample stage.

CAUTION

Do not allow the temperature on any stage to raise more than 10 K above room temperature when the system is not being actively cooled. Carefully observe all temperature readings and be ready to turn the heater off if any stage raises more than 10 K above room temperature.

4. Use TABLE 3-3 to set the sample stage’s sensor and heater.
5. Monitor the temperature reading. Within 10 min the stage should raise approximately 5 K and begin to stabilize. The heater output for the chosen stage should then reduce below 100% and begin to stabilize. This demonstrates that the sensor and heater are functioning properly and that the control loop is closed.

NOTE

If you are not flowing cryogen, the temperature will settle to a temperature above the actual setpoint.

6. Turn the sample stage heater off.
7. Set the temperature setpoint to zero.
8. Repeat steps 4 to 7 for the remaining stages, one at a time.

If any of the stages do not raise 5 K and stabilize, the most likely reason for the failure is the cabling; there may be a cable plugged into the wrong connector. Refer to the wiring diagram in section 6.4.3. If the wiring diagram does not reveal the problem, contact a Lake Shore representative for assistance.

	Sample stage	4 K shield stage	Radiation shield stage	Second shield stage
Controller	Model 340	Model 340	Model 332	Model 332
Loop and channel	Loop 1, input A	Loop 2, input B	Loop 2, input A	Loop 1, input B
Temperature setpoint	5 K above room temperature	5 K above room temperature	5 K above room temperature	5 K above room temperature
Heater	On, max heater range	On	On	On, high
Heater indicator light	—	Channel 1 light on the Model 142 linear amplifier	Channel 2 light on the Model 142 linear amplifier	—

TABLE 3-3 ***Controller settings for temperature sensor and heater test***

3.6.3 Microscope Light and Focus Test

Follow this procedure to ensure that the microscope focuses properly on the sample stage. See section 2.3.6.1 for a sample of approximate focal clarity when you use the focus aid with the Zoom 70 and Zoom 160.

1. Place a piece of sample material or sample substrate on the sample holder. We recommend using an optical target such as the U.S.A.F. optical target for resolution verification.
2. Install the radiation shield lid and the vacuum chamber lid (see section 4.3.5).
3. Refer to section 4.6.1 to use the microscope to image the sample.
4. If the microscope will not focus on the target, refer to section 6.3.4.
5. If the image is not oriented as desired, refer to section 6.3.4.8.

3.6.4 Testing the Probe Arm Reach

Follow this procedure to check the probe arm reach.

1. Remove the vacuum chamber lid and radiation shield lid (section 4.3.1).
2. Use the z-axis micrometers to raise all probes up 3 mm to 4 mm above the sample stage.
3. Slowly move one probe towards the sample stage using the x-axis hand dial.
4. Watch for interference of the probe, cable connector and blades.
5. Using the x and y-micrometers to adjust position, move the probe (it should travel smoothly) until the probe tip reaches all sides of the specified 25 mm (1 in) diameter probe area (see FIGURE 4-1 for probe area).
6. Retract the probe and repeat for all other probes.

CAUTION

Check arm reach one probe arm at a time. Retract the previously checked arm before advancing a second arm into the sample area. Failure to comply may result in probe tip damage.

3.6.5 Probe Continuity Test

Follow this procedure to ensure that the probes have been installed correctly and will transmit a signal when probing a sample. The radiation and vacuum chamber lids do not need to be installed. This procedure should be performed whenever a probe arm or probe has been changed.

1. Land each probe tip on the top surface of the grounded sample holder.
2. Using a multimeter, measure continuity (resistance) between each adjacent pair of probes.
3. A bad probe assembly can be identified if it does not show continuity (low resistance) with the probes on either side.
4. If a probe assembly appears bad, first re-land the probe to make sure it is touching the sample stage, then refer to section 6.3.5.

3.6.6 Vacuum Chamber Leak Test

Follow this procedure to verify vacuum chamber integrity.

1. Test the turbo vacuum pump along with the connection to the probe station (section 6.3.1.2).
2. Test the turbo vacuum pump, connection to the probe station, and the probe station vacuum chamber (section 6.3.1.3).

CAUTION

Failure to turn off and properly vent the vacuum before opening the vacuum isolation valve may result in damage to your vacuum pumping system.

Chapter 4: Basic Operation

4.1 General

This chapter describes the majority of daily operation. Chapter 5 covers more advanced probe station operation. It is assumed that the station has been installed and set up as described in Chapter 3.

4.1.1 Common Operational Mistakes

The following are some common mistakes that can be made while operating the probe station. These mistakes can result in costly damage to the probes or refrigerator. Please read this chapter thoroughly before operating the probe station for the first time so that these and other mistakes can be avoided.

- Opening the vacuum chamber to atmosphere with a cold refrigerator
- Heating the refrigerator when not under vacuum
- Heating the refrigerator when not flowing cryogen
- Not raising the probe tips before evacuating the chamber
- Not raising the probe tips before changing temperature
- Not checking that all probe tips can contact the sample under test before initiating a cryogen transfer

4.1.2 Temperature Limits

The maximum temperature limits for the multiple stages and components of the probe station are listed below. Adhere to these limits at all times during probe station operation.

Sample stage:	475 K
4 K shield stage:	380 K
Radiation shield stage:	380 K
Second shield stage:	380 K
Probe arms:	350 K

CAUTION

Optional probes and sample holders may have lower maximum temperatures. Failure to observe maximum temperatures may result in equipment damage.

4.2 Operating the Probe Arm Translation Stages

Each probe assembly includes a micro-manipulated translation stage with three axes of motion that are described in this section. All six available probes can be positioned in a 25 mm (1 in) diameter probe area in the center of the sample holder (FIGURE 4-1). The CPX can accommodate 32 mm (1.25) and 51 mm (2 in) sample holders, but the probe area is the same for both sizes. Individual probes can land outside the probe area in line with the probe arm. Due to translation limitations, individual probes cannot be landed on either side of the defined probe area. The sample should be positioned and aligned on the sample holder to take best advantage of the probe area (see section 4.3.3.1 for alignment).

CAUTION

Before evacuating the vacuum chamber or making significant temperature changes, use the z-axis micrometers to raise all probes up 3 mm to 4 mm above the sample. Failure to do so will potentially cause damage to the probe tip or scratch the sample surface.

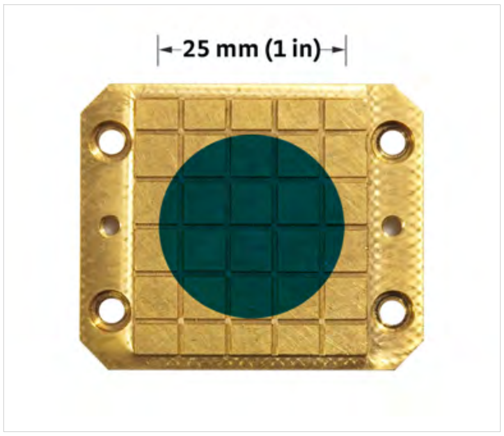


FIGURE 4-1 ***Probe area indicated with blue circle***

Normal motion of the translation stages remains smooth with constant turning force throughout the usable range. It is normal, however, for additional tension to occur when the system is under vacuum as compared to when it is open. Restrictions in motion are normally caused by the stage coming to the end of its travel. Restriction can sometimes also be caused by interference inside the chamber. In either case, never force one of the controls or damage to the probe or refrigerator may result. Instead, remove the vacuum chamber lid and radiation shield (section 4.3.1), and identify the restriction before proceeding.

CAUTION

The probe arm translation stage has a greater range of motion than is accommodated by the CPX sample stage and radiation stages. When moving the probe beyond the opposite end of the sample holder, take precautions to ensure nothing interferes with the probe, or you may risk damaging the probe tip.

The following translation stage controls are used to position the probe. Please note that these instructions apply only to stages like the one pictured in FIGURE 4-2. Other probe station models will operate differently.

The *X-axis* hand dial is used to move the probe in and out (in the probe arm axis) with a total travel of 51 mm (2 in). Turning the hand dial clockwise moves the probe toward the sample. The graduated scale on the side of the stage shows 1 mm divisions. The graduated scale on the hand dial shows 0.02 mm divisions.

The *Y-axis* micrometer is used to move the probe from side to side (along the plane of the sample perpendicular to the probe axis) with a total travel of 25 mm (1 in). Turning the micrometerclockwise moves the probe to the left. One complete revolution of the micrometer moves the probe 0.5 mm. The graduated scale on the outside of the micrometer shows 0.01 mm divisions.

The *Z-axis* micrometer is used to move the probe up and down (vertically) with a total travel of 18 mm (0.71 in). Turning the micrometer clockwise moves the probe down. One complete revolution of the micrometer moves the probe 0.5 mm. The graduated scale on the outside of the micrometer shows 0.01 mm divisions.

For those probe assemblies that are shipped with microwave probes, planarization (rotation) of the probe arm is described in section 4.6.4. Installation of the planarization assembly is given in section 5.3.8.

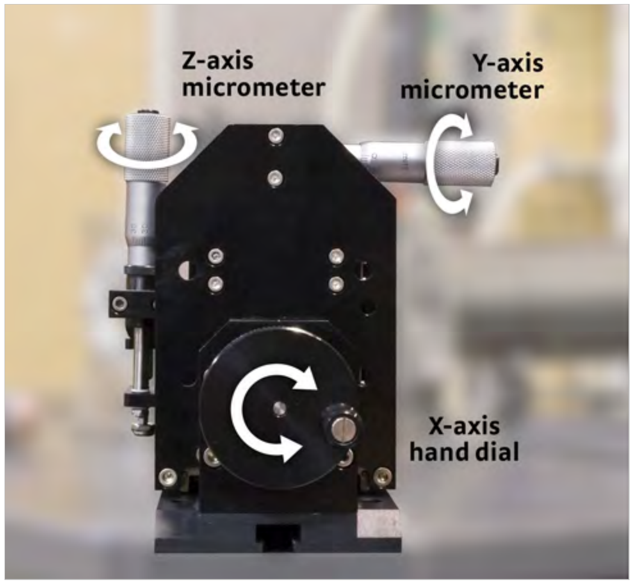


FIGURE 4-2 ***Micro-manipulated stage illustrating the axes***

4.3 Sample Exchange

This section covers the steps required to load and unload a sample.

CAUTION

Wear nitrile gloves when handling anything inside the probe station. Hand oils will contaminate the surfaces, resulting in poor vacuum and thermal performance.

4.3.1 Opening the Vacuum Chamber and Radiation Shield

The probe station should always be stored with the system under vacuum to help prevent contamination and oxidation. This section is written assuming the chamber is under vacuum, the vacuum pump is turned off, and the vacuum isolation valve is closed. Follow this procedure to open the vacuum chamber and radiation shield.

1. *Raise* each probe 3 mm to 4 mm above the sample holder using the z-axis micrometers.
2. *Center* all probes using the y-axis micrometers.
3. *Retract* all probes away from the sample stage using the x-axis hand dials. This will provide maximum access to the sample stage.
4. *Recommended:* connect a tank of dry, inert gas such as nitrogen or argon to the purge valve and follow the instructions for purging the vacuum chamber (section 4.4.4). Input 6.9 kPa to 13.8 kPa (1 to 2 psi) into the chamber during the remainder of this procedure.
   Alternate: to release the vacuum to atmosphere, slowly open the purge valve by turning the hand knob on the top of the valve counterclockwise.
5. Using the 2.5 mm hex driver, unlock the four captive quarter-turn fasteners on the vacuum chamber lid.

FIGURE 4-3 ***Left: Vacuum isolation valve on the probe station; Right: Probe station vacuum chamber lid removal***

6. Pull up gently on the lid to remove it. A light bump may be required to release the o-ring seal if the chamber was closed for a long time.
7. Place the vacuum chamber lid in a safe place where it will not get scratched or contaminated.
8. Using the 2.5 mm hex driver, loosen the eight M3 screws from the outer edge of the radiation shield lid. The screws are captive and stay with the radiation shield lid.
9. Place the radiation shield lid with the vacuum chamber lid. Bumpers are built into the radiation shield lid for it to rest on.

4.3.2 Removing the Sample Holder

Follow this procedure to remove the sample holder.

1. If you are removing an optional triaxial or coaxial sample holder, disconnect the signal cable before removing the sample holder from the sample stage (FIGURE 4-4). Using tweezers or your fingers, pull the cable plug out of the sample holder socket. The cable can be left as shown in FIGURE 4-4.

CAUTION

Be very careful that the tweezers do not slip off the cable plug and onto the wire, where they can accidentally pull the wire out of the connector.

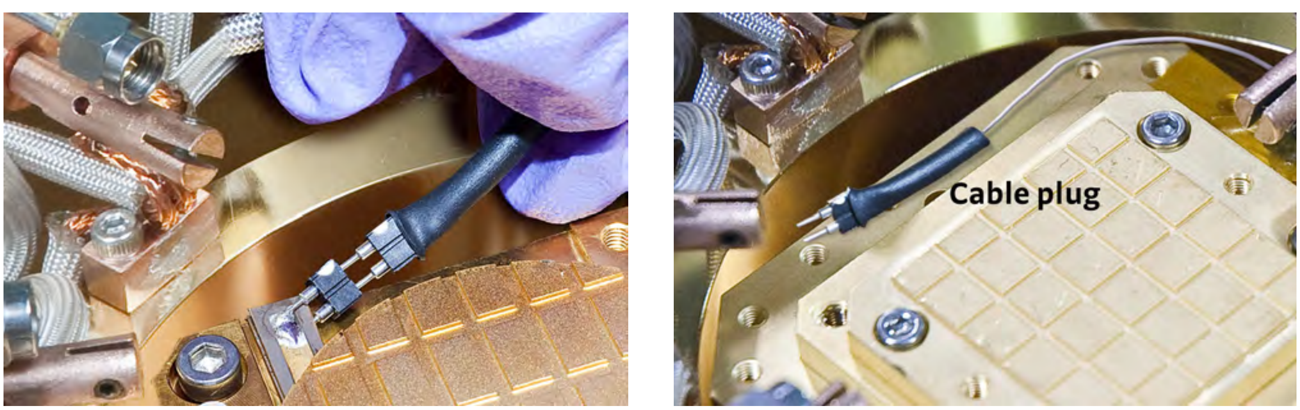


FIGURE 4-4 ***Left: Disconnecting the triaxial sample holder; Right: Cable plug left out after disconnecting***

2. Screw the lifter tool into the sample holder. There are two holes available for the lifter. Use the most convenient (FIGURE 4-5).
3. Using the 2.5 mm hex driver, loosen the four M3 screws. Be careful not to drop them inside the chamber.
4. Lift the screws out with tweezers, or leave them in their holes and lift them out with the sample holder.

5. Using the lifter tool, lift out the sample holder and screws. Store the sample holder in a clean place until needed.
6. If the probe station is not going to be used immediately, it should be reassembled and evacuated.

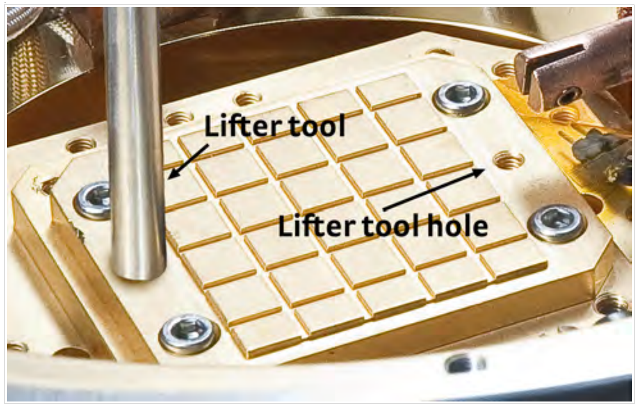


FIGURE 4-5 ***Lifter tool screwed into a lifter tool hole***

4.3.3 Mounting Samples on the Sample Holder

The sample must be properly mounted to the sample holder so that the two are in close thermal contact. If the sample is not properly mounted, the sample can deviate from the temperature read by the sample stage temperature sensor, causing errors in measurement data. The temperature error can be significant, especially at cryogenic temperatures. Before choosing a method to mount your sample, it is important to understand how to align your sample, and how to minimize the risk for cracking wafers. Additional sample holders can be ordered so that new samples can be mounted while others are being probed.

4.3.3.1 Sample Alignment and Position

Remove the sample holder from the sample stage (section 4.3.2) for best access and ease of alignment. Align the patterning of the wafer parallel to the grooves in the sample holder. This ensures that the probe arms will intersect the wafer patterns at right angles.

Whole, 25 mm (1 in), wafers must be centered on the sample holder in order to fit onto the sample stage, to take advantage of the probe area (see FIGURE 4-1 for an image of the probe area). Smaller samples should also be centered to allow easy access by all probes.

Extra care must be taken aligning samples when using GSG microwave probes, because each probe must land all three points on the sample (see section 4.6.3). After the sample holder is secured in the probe station, test the alignment to be sure that all probe points can contact the sample (section 4.6.3 and section 4.6.4). Remember to lift the probes before evacuating the chamber.

4.3.3.2 Reducing the Risk of Cracking Wafers

Larger, whole wafers pose the most difficult challenge for sample mounting. Good thermal contact with the sample holder is desirable to prevent thermal gradients across the wafer but, because of their size, differences in thermal expansion can cause the wafer to crack when cooled.

There are two common methods for reducing the risk of cracking wafers.
Flexible Mounting: flexible mounting methods, like vacuum compatible grease, allow the sample and sample holder to expand and contract at different rates. Be careful at very low temperatures because some types of grease freeze and become solid.

Reduce Gradients: cool and warm the system slowly using the setpoint ramp feature of the temperature controller to reduce temperature gradients across the sample. Consult the temperature controller manual for details on the setpoint ramp feature.

4.3.3.3 Temporary Mounting

Temporary mounting is the most common mounting technique among probe station users. It is easy and fast but still gives reasonable results for most applications. These are the four most common methods for temporarily mounting samples.

1. *Vacuum Compatible (Low Vapor Pressure) Grease:* Apiezon N® grease works well to improve thermal contact at cryogenic temperatures. Apiezon N® grease has a specified operating range of 1 K to 300 K. At lower temperatures it freezes, changing its physical and thermal properties. At warmer temperatures (316 K) it melts and becomes less tacky. To use grease, brush a very light coat on the top surface of a clean sample holder. You have applied too much grease if the grooves on the sample holder become filled. Apiezon N® grease is available from Lake Shore.
2. *Clamping:* a small amount of pressure applied with clamps can significantly improve thermal contact between the sample and sample holder. Clamping can also be used to improve the effectiveness of grease as a thermal contact. Users often make simple clamping fingers to fit their sample and hold them down with M3 screws in the tapped holes intended for the lifter tool.
3. *Adhesive Tape:* tape over the corners or edges of a sample with vacuum compatible tape that has a silicon adhesive. Experience has proven that 3M brand Kapton® tape with silicon adhesive will retain its adhesive properties to as low as 4 K.
4. *Double-sided Adhesive Tape:* if there is no room on the top surface for Kapton® tape, double-sided tape can be placed between the sample and sample holder. Some experimentation may be required to find a tape that does not harden and peel away at low temperatures.

With all of the adhesive methods, the sample holder top surface can be cleaned with acetone applied to a soft, clean cloth then rinsed with isopropyl alcohol. Do not use abrasives or scrub the sample holder, because the gold plating will be removed.

4.3.3.4 Semi-Permanent Mounting

Semi-permanent mounting gives better thermal contact than temporary mounting, but it requires more time to mount and remove the sample.

1. *VGE 7031 varnish:* you can use VGE-7031 varnish in temperatures ranging from 2 K to 470 K, and it is compatible with the grounded, isolated, coaxial and triaxial sample holders. VGE-7031 varnish is available through Lake Shore.
   - To mount: only a small amount of varnish is needed for your sample. For a 25 mm (1 in) sample, place a drop of the varnish on three pads of the sample holder. Then center and align the wafer on the sample holder. The amount of varnish used can be increased or decreased for larger or smaller samples, respectively. VGE-7031 varnish may be air dried or baked according to manufacturer's recommendations.
   - To remove: you can remove the sample by soaking in ethanol or toluene. A solution of equal parts of ethanol and toluene has also been very successful at removing samples mounted with VGE-7031 varnish. Grooves in the sample holder permit the remover to flow under the sample.
2. *Photoresist or PMMA material:* the most common semi-permanent mounting technique is photoresist or PMMA material common to the semiconductor processing industry. It offers excellent adhesion yet is still removable.

CAUTION

The photoresist, chemical remover, and bake procedures must be compatible with the wafer and devices. These processes are compatible with grounded and isolated sample holders. Please note that coaxial and triaxial sample holders contain Kapton® insulation; any chemicals used must be compatible with this. Also, for the coaxial and triaxial sample holders, temperatures should not exceed 400 K.

- To mount: put a drop of the photoresist on three pads of the sample holder. Center and align the wafer onto the sample holder and bake using the usual specifications for the resist.
- To remove: you can remove the sample by soaking in chemical remover. Grooves in the sample holder permit the remover to flow under the sample.

3. *Silver paint:* if an electrically conductive mounting is required, silver paint can be used in place of photoresists or VGE-7031 varnish. Please note that the paint must be dried completely for best electrical conduction.
   - To mount: only a small amount of silver paint is needed for your sample. For a 25 mm (1 in) sample, place a drop of the silver paint on three pads of the sample holder. Center and align the wafer onto the sample holder. The amount of silver paint used can be increased or decreased for larger or smaller samples, respectively. Silver paint may be air dried or baked according to manufacturer's recommendations.
   - To remove: you can remove the silver paint by soaking it in acetone.

4.3.3.5 Permanent Mounting

Permanent mounting is generally considered a last resort if all other methods have failed to give adequate performance. These methods generally do permanent damage to the sample, sample holder or both. Low temperature solder and filled epoxy (Stycast®) are permanent mounting options that are compatible with vacuum.

4.3.4 Mounting the Sample Holder onto the Sample Stage

Follow this procedure to mount the sample holder onto the sample stage.

1. *Raise* each probe 3 mm to 4 mm above the sample holder using the z-axis micrometers.
2. *Center* all probes using the y-axis micrometers.
3. *Retract* all probes away from the sample stage using the x-axis hand dials. This will provide maximum access to the sample stage.
4. Lower the sample holder onto the sample stage using the lifter tool (FIGURE 4-6).
5. If mounting an optional triaxial or coaxial sample holder, align the socket on the sample holder with the cable location.
6. Using the 2.5 mm hex driver, fasten the sample holder to the sample stage by starting all four M3 screws in a few threads before tightening any screws to prevent cross-threading.
7. Tighten the four screws securely; this is the source of thermal contact between the sample holder and the sample stage. It is best to tighten all four screws a little at a time until snug.

CAUTION

Do not over-tighten, as damage to the sample stage threads is costly to repair.

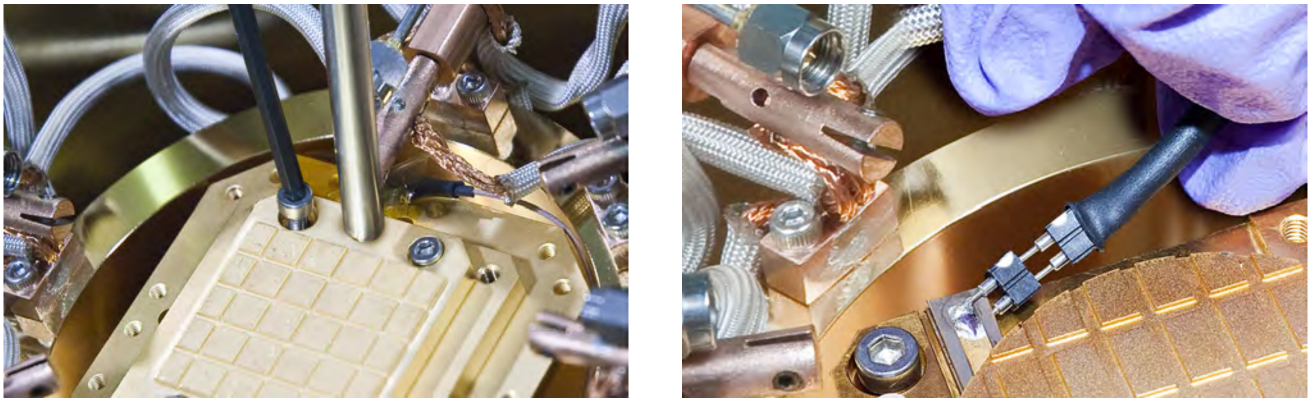


FIGURE 4-6 ***Left: Fastening the sample holder onto the sample stage; Right: Connecting the signal cable on a triaxial or coaxial sample holder***

8. If mounting an optional triaxial or coaxial sample holder, connect the signal cable after mounting the sample holder to the sample stage (FIGURE 4-6). Using tweezers , push the cable plug into the sample holder socket.

CAUTION

Be very careful that the tweezers do not slip off the cable plug and onto the wire, where they can accidentally pull the wire out of the connector.

9. If you are using microwave probes, make sure rotation and planarization are within range (section 4.6.3 and section 4.6.4)

4.3.5 Closing the Vacuum Chamber and Radiation Shield

Follow this procedure to close the vacuum chamber and radiation shield.

NOTE

Lake Shore recommends that you practice imaging the sample and landing the probes (section 4.6) before closing the vacuum chamber and radiation shield for cooldown.

1. Using the 2.5 mm hex driver, attach the radiation shield lid to the radiation shield body. Start all M3 screws in a few threads before tightening any screws to prevent cross-threading (FIGURE 4-7).
2. Securely tighten all eight screws; this is the source of thermal contact between the lid and shield body.

FIGURE 4-7 ***Attaching the lid to the radiation shield body***

3. Clean the o-ring groove in the vacuum chamber. Clean, inspect and lightly grease the o-ring with vacuum grease and place it in the groove. (FIGURE 4-8). Make sure that the o-ring does not twist as it is being installed.
4. Place the vacuum chamber lid onto the o-ring (FIGURE 4-8).

5. Push down squarely on the vacuum chamber lid and turn the quarter-turn fasteners until they lock into place. Do not attempt to tighten the fasteners, as the vacuum force will draw the lid down and form a tight seal.

CAUTION **The quarter turn fasteners should never be forced; if they do not engage smoothly, push down firmly on the vacuum chamber lid before engaging them.**

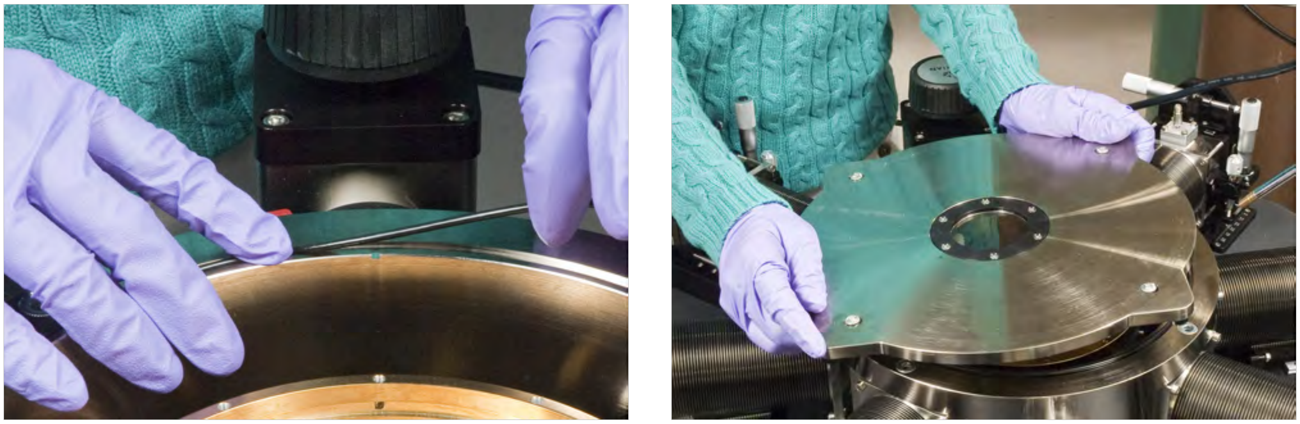


FIGURE 4-8 ***Left: Placing the o-ring in the chamber groove; Right: Placing the chamber lid onto the o-ring***

4.4 Vacuum Operation

The vacuum system is one of the biggest variables in the probe station hardware configuration. Clean, consistent vacuum is critical to probe station performance and should be given careful consideration during operation.

This section outlines some of the operating characteristics of a typical vacuum system using the Lake Shore Model PS-V81DP option as an example; refer to section 2.3.7 for equivalent specifications. Most of the principles described here are applicable to other vacuum systems. Please take time to become familiar with the components of your turbo pumping system and their operation before continuing.

4.4.1 Turbo Pump Overview

The most difficult part of operating a turbo pumping system is keeping the proper sequencing. The turbo pumping system option offered by Lake Shore includes a vacuum controller for automatic sequencing of turbo turn on and turn off operations. The vacuum controller has safety limits to help prevent damage to the vacuum equipment. For example, the turbo pump may be damaged if it is turned on before the fore pump brings the vacuum level down to an acceptable level; the turbo controller is designed to prevent this from happening. Lake Shore turbo pumping systems are shipped set to the pump manufacturer's factory defaults that work well for probe station operation.

4.4.1.1 Vacuum Controls

In addition to the obvious power switch configuration on the turbo pumping system, there are three more valve controls that need to be understood for proper vacuum operation. These are the purge valve, vacuum isolation valve, and turbo vent valve. The purge valve and vacuum isolation valve are located on the probe station vacuum chamber and are always operated manually. Some turbo pumping systems include an automatic venting feature for the turbo pump, but most are manual. Specific instructions for vacuum operation are included in the remainder of this section and section 4.5.

General descriptions and recommendations for these controls are given below; however, your pump manufacturer's recommendations should always take precedence.

- *Purge Valve:* the purge valve shown in FIGURE 4-9 is used to backfill the chamber with dry nitrogen or inert gas. It is most commonly used when warming or venting the system.
- *Vacuum Isolation Valve:* the vacuum chamber and turbo pumping system are separated by the vacuum isolation valve located on the probe station. The valve has two potential uses during operation. It can be used to help maintain the cleanest possible vacuum in the chamber as described in section 4.4.1.2 and it allows separation from the pumping system to reduce vibration during cryogenic operation. In the sequence of operations, the vacuum isolation valve can always be opened safely if the vacuum level on each side of the valve is the same.
- *Manual Turbo Vent Valve:* turbo pump performance relies on precision blades that must be kept in balance at all times. The vent valve on the turbo pump is used to vent the pump system while keeping the blades in balance. The precision blades can be damaged if the pump system is vented through the turbo pump inlet by opening the vacuum isolation valve.
- *Automatic Turbo Vent Valve:* some turbo pump systems are programmed to automatically vent when they are turned off or lose power. A few seconds after the pumping system is powered off, an automatic valve will backfill room air through the pump, safely venting the pump system and shutting the turbo pump down. However, if the pump vents while the refrigerator is cold, water vapor will condense on the refrigerator and freeze into damaging ice. It can take approximately a week to return the probe station to proper working order (if this does happen, please refer to section 6.2.12). It is possible that the refrigerator may suffer irreparable damage.

! CAUTION

Close the isolation valve when the refrigerator is cold to prevent the chamber from being vented if the pump is accidentally turned off or the vacuum pump loses power. Venting the chamber when the refrigerator is cold can damage the probe station.

4.4.1.2 Considerations for Using the Vacuum Isolation Valve

If the probe station is going to be cryogenically cooled with liquid helium, it is best to close the isolation valve and turn off the vacuum pump when the refrigerator temperature is less than 100 K. The cooled radiation shields act as a cryopump, creating a better vacuum than the turbo pump. In the case where cryopumping reduces the vacuum pressure in the chamber below that of the turbo pump, it is even possible to draw outside contamination in through the vacuum system. Turning the pump off also minimizes vibration at the sample.

If the probe station is going to be operated without cryogenic cooling (see section 5.2.4), it is best to leave the vacuum isolation valve open and the pump running during operation. This is because at elevated temperatures the system will slowly outgas and degrade the vacuum. The pump line isolation option (PS-PLVI-40) should be used if measurements are routinely made at elevated temperatures to reduce vibrations due to the vacuum pump.

4.4.1.3 Vacuum Gauge Location

For convenience, the vacuum gauge on the PS-V81DP pump option is located on an NW 40 T immediately at the inlet of the turbo pump. Vacuum pressures in the probe station chamber will be a half order of a magnitude higher than measured here. All probe station vacuum specifications are made with the gauge located on the vacuum chamber itself. For more accurate vacuum pressure readings the gauge can be moved to an available port on the vacuum chamber.

4.4.1.4 Vacuum Performance

A room temperature vacuum level of <10^{-3} Torr in the vacuum chamber is required for the probe station to meet its specified base temperature and cooling time. Each probe station is tested prior to shipment to ensure it can achieve appropriate vacuum level and cooling specifications with a PS-V81DP turbo pump option.

If the system will not reach a vacuum level of <10^{-3} Torr within 1 h, or it takes more than 10 min for the turbo pump to reach full speed, suspect a leak or other problem with the vacuum system and refer to section 6.3.1.8 for troubleshooting information.

Even with properly functioning equipment and good maintenance, vacuum performance of the probe station may degrade with time. The probe station may need to be warmed up and re-evacuated if it has been in continuous operation for several days or if the sample is warmed and cooled frequently.

To keep the vacuum system operating efficiently, refer to section 6.2.1 for a preventive maintenance schedule .

4.4.2 Evacuating the Vacuum Chamber

After closing the vacuum chamber lid, follow this procedure to evacuate the system. This process assumes that the vacuum pump is off when beginning.

1. Use the z-axis micrometers to raise all probes 3 mm to 4 mm above the sample. Failure to do so will potentially cause damage to the probe tip or scratch the sample surface.
2. Close the purge valve completely (FIGURE 4-9).
3. Verify that the vacuum pump is turned off and properly vented (close the manual vent valve).
4. Open the vacuum isolation valve completely (FIGURE 4-9).

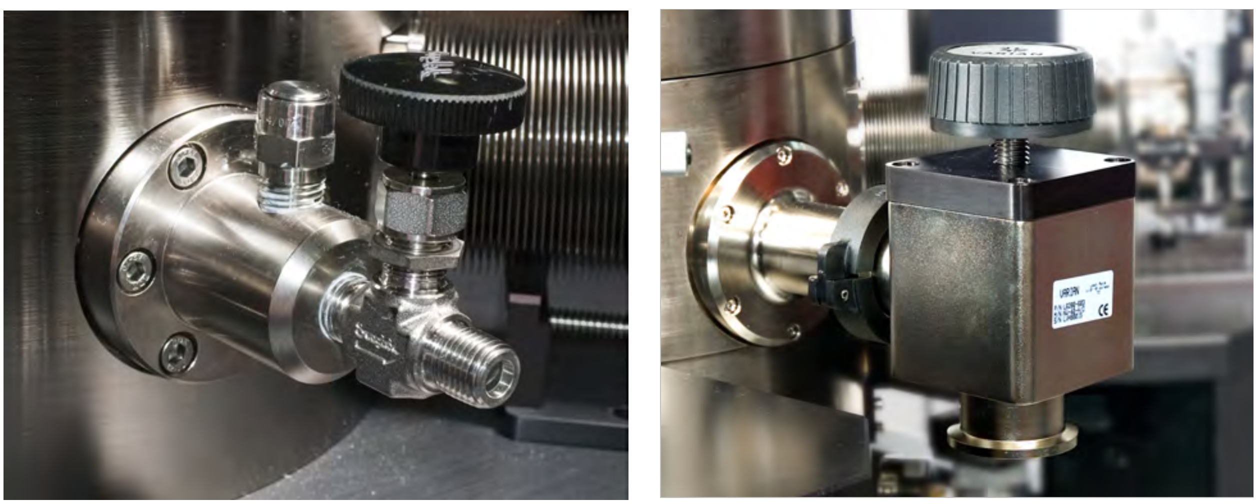


FIGURE 4-9 ***Left: Purge valve; Right: Vacuum isolation valve***

5. Start the turbo pumping system. The steps to power on the system follow:
    a. Switch the main power rocker switch to the up position, which powers on the entire unit.
    b. Switch the scroll pump knob from position 0 to position 1 to start the roughing pump.
    c. Press the start button on the turbo pump controller to engage the turbo pump. If the controller is set in remote mode, the turbo pump will automatically start and stop with the scroll pump knob.
6. Observe to be sure it starts rotating up to its maximum operational speed.

7. If the vacuum gauge readout is not currently displayed on the turbo controller front panel, push the measures button on the controller front panel to cycle through various pump diagnostics until the vacuum gauge readout is displayed.

The flexible stainless steel vacuum line should immediately begin to stiffen. The vacuum gauge should begin reading in approximately 3 min. The turbo pump should reach full speed in approximately 5 min. The chamber should pump below $<10^{-3}$ Torr in approximately 30 to 60 min. If it does not, refer to section 6.3.1.8 for troubleshooting.

At this point in the process, operation of the vacuum pump and isolation valve are dependent on the intended application.

4.4.3 Shutting Down the Turbo Pump

Follow this procedure to shut down the turbo pumping system. This procedure assumes that the system is sealed and under vacuum.

1. Close the vacuum isolation valve.
2. Press the stop button on the vacuum turbo pump controller to disengage the turbo pump.
3. Switch the scroll pump knob from position 1 to position 0 to stop the roughing pump.
4. Open the manual vent valve located on the side of the turbo pump to vent the turbo pumping system. In order to increase the lifetime of the turbo pump, it is always recommended to vent the pumping system through the manual vent valve and not simply allow atmospheric air to rush into the inlet.
5. You will hear hissing as the manual vent valve is opened and air rushes into the turbo pump. Once the hissing ceases, completely close the manual vent valve.

It is acceptable to leave the main power rocker switch in the on position when not operating the vacuum pumping system.

Remember you will always need to purge the vacuum chamber and open the vacuum isolation valve before restarting the pump.

CAUTION

Never vent the turbo pump through the vacuum isolation valve whether the pump is turned on or turned off. Although this will not immediately destroy the vacuum pump, it will likely stall the pump and decrease its life. Always close the vacuum isolation valve, turn off the pumping system, and open the turbo vent valve if the valve is not configured to open automatically.

4.4.4 Purging the Vacuum Chamber

The purge valve shown in FIGURE 4-9 is used to backfill the chamber with dry nitrogen or inert gas. It is most commonly used when warming or venting the system. During warm up, backfilling with inert gas can speed the warm up process (section 4.5.6, step 7). When opening a warm system, backfilling with dry nitrogen gas will prevent moisture and contaminants from entering the chamber, which will reduce pump-down time and improve vacuum quality.

If the system is accidentally left open for a long period of time, it should be cycle-purged to reduce contamination. In this technique, the chamber is evacuated, purged with dry argon and evacuated again.

WARNING

The vacuum chamber is not designed for positive pressure and should never be pressurized above 2.1 kPa (0.5 psi). The pressure relief valve on the chamber is set for 0.5 psi and should never be disabled or modified. Failure to comply may result in injury or death.

WARNING

The vacuum chamber should only be backfilled with dry nitrogen or inert gas. Failure to comply may result in injury or death or damage to the probe station.

CAUTION **Never purge the chamber unless all stages of the refrigerator are above 100 K.**

CAUTION **Never vent the chamber to atmosphere unless all refrigerator stages are above 290 K.**

Follow this procedure to purge the vacuum chamber. This process assumes the turbo pump has been properly shut down according to section 4.4.3.

1. Attach a dry nitrogen or inert gas line to the purge valve. We recommend you purge to dry nitrogen instead of purging to air in order to increase and maintain the pumping efficiency of the system.
2. Regulate the gas pressure to 6.89 kPa to 13.79 kPa (1 to 2 psi).
3. Open the purge valve slowly. In about one minute, the pressure relief valve on the chamber will open and release gas.

If the system is going to be opened for sample exchange, remove the vacuum chamber lid with the gas flowing. The dry inert gas will prevent atmospheric air from entering the chamber; this will speed vacuum pump down times. Close the purge valve when the vacuum chamber lid is replaced. If it needs to remain open for an extended period of time, replace the chamber lid and shut the gas off.

4.5 Temperature Operation

This section describes basic temperature operation of the probe station; advanced temperature operation will be discussed in Chapter 5. Before performing any of the operations, the system must be closed and evacuated as described in section 4.4.2. Often, there are multiple ways of performing some of these procedures, but we have chosen steps that represent a good balance between ease of operation and minimizing helium consumption.

4.5.1 Basic Cryogen Handling

Liquid cryogen is a safe, effective and economical cooling source when handled with appropriate respect. Please follow the operating instructions and carefully read each warning and caution before performing cooling operations. This information is provided to protect both operator safety and the probe station from damage.

WARNING **Wear cryogenic gloves, safety glasses, long sleeves, and long pants. Due to the extremely low temperatures of liquid nitrogen (77 K), and liquid helium (<4.3 K), caution should be exercised when handling or transferring it. Failure to comply may result in severe frostbite injury.**

WARNING **All cryogen Dewars should be clearly labeled and operated in accordance with the manufacturer's instructions. The pressure relief devices should be periodically inspected and any ice formation removed.**

WARNING **Do not use cryogenic gases in confined spaces; ensure that the room is ventilated. As liquid cryogen vaporizes, it expands and displaces oxygen. Failure to vent large quantities of vaporized cryogen can result in a loss of consciousness or death.**

CAUTION **Never cool the system if the vacuum chamber is not evacuated.**

4.5.2 Controls for Temperature Operation

The CPX uses five mechanical controls and four electronic control loops (one for each refrigerator stage) to establish and regulate temperature. This section details the mechanical controls first, followed by the electronic controls.

4.5.2.1 Mechanical Refrigerator Controls

The mechanical controls on the CPX are used to regulate the amount of cryogen flowing though the refrigerator and establish its nominal cooling behavior.

Transfer Line Foot Valve Control Knob: this is the primary means for setting the rate of cryogen flow into the refrigerator. Both the sample and radiation shield stages are supplied by the same source, so the foot valve sets the total for both paths. The valve is generally opened counterclockwise six to nine full turns to allow maximum flow during system cooldown. It is usually set to only one to two turns open after cooldown to help conserve cryogen.

NOTE **The control does not have a stop on the open side; therefore, it can unthread if it is opened too far. You should never need to open it more than nine turns. If you inadvertently unthread it too far, gently push it back together and rotate the control valve clockwise to re-seat the threads.**

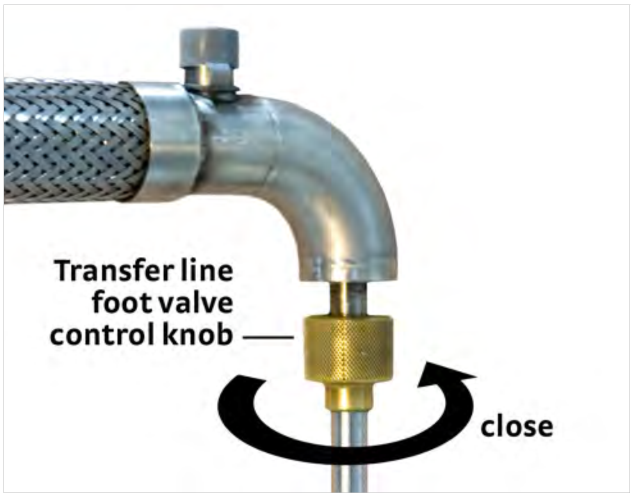


FIGURE 4-10 ***Transfer line foot valve control knob***

Pressure Regulator: pressure is required in the Dewar to push cryogen through the transfer line into the refrigerator. Higher pressure (55 to 69 kPa; 8 to 10 psi) allows maximum flow during cooldown. Lower pressure (21 to 34 kPa; 3 to 5 psi) is recommended for normal operation. Dry, pure gaseous nitrogen should be used for LN_2 transfers and dry, pure gaseous helium for LHe transfers.

Sample Stage Micrometer Valve: this restricts the cryogen flow to the sample stage while permitting unrestricted flow to the 4 K shield and other radiation stages. The valve is opened five to six turns when cooling the sample stage. It is opened two turns or less when operating the sample stage either above or below the 4 K shield stage temperature. The control does not have a stop on the open side; therefore, it can unthread if it is opened too far. You should never need to open it more than nine turns. If you inadvertently unthread it too far, gently push up on the micrometer control and turn it in the closed direction.

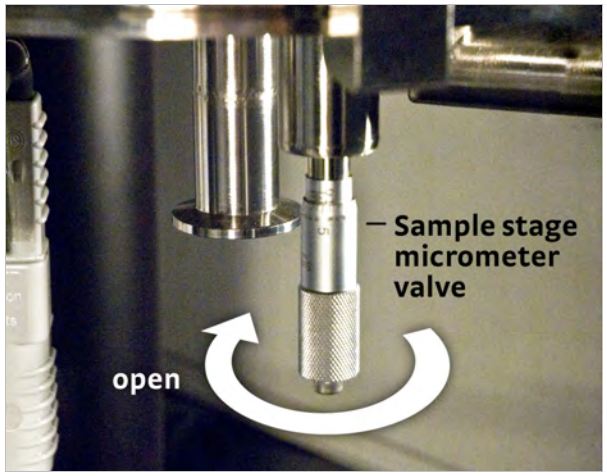


FIGURE 4-11 **Sample stage micrometer valve**

Dual Valve Assembly: this is used only when operating the sample stage below 4.2 K (as part of the PS-LT option). These valves work with the sample stage micrometer valve to create vacuum pressure on the helium in the sample stage, which lowers its temperature. Refer to section 5.2.2 for operating below 4.2 K.

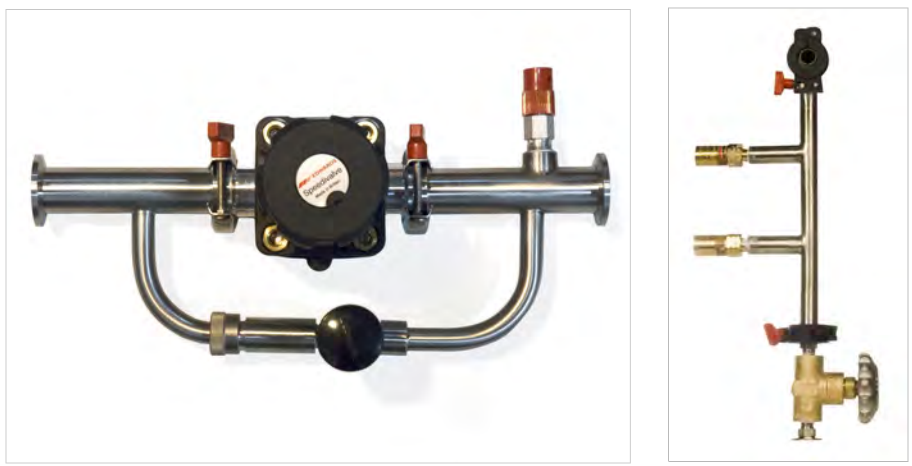


FIGURE 4-12 **Left: Dual valve assembly; Right: Exhaust valve assembly**

Exhaust Valve Assembly: this is used only when the sample stage was operated above 100 K, and it needs to be cooled back down to a lower operating temperature. The valve allows back-pressure in the 4 K shield stage cryogen flow path to force cryogen into the sample stage. Otherwise, the warmer sample stage may block the flow of cryogen.

4.5.2.2 Electronic Temperature Controls

Model 340 and Model 332 temperature controllers provide the electronic control of the CPX refrigerator temperature. They work with a Model 142 auxiliary amplifier, which provides additional heating power. The Model 340 and 332 operate a total of four closed loop, PID (proportional, integral, derivative) control loops (refer to Chapter 2 of the instrument manuals for details).

Each refrigerator stage includes a temperature sensor, which is the control input for each loop, and a heater, which is the control output for each loop. The controller balances its heater power against the cooling power of the cryogen flowing through the refrigerator at a desired temperature setpoint. Since the controller cannot contribute cooling power, the setpoint must be higher in temperature than the base temperature of the refrigerator for the controller to operate properly.

CAUTION

If the controller is configured improperly, the controller can provide enough heat to damage the refrigerator.

The controllers are configured at Lake Shore as described in the temperature controller configuration table (TABLE 4-1). However, the controller settings should be re-verified any time the system is moved, serviced or reconfigured (section 3.6.1.3).

The sample stage is the only stage actively controlled during normal operation. The other control loop setpoints should be set to zero or the heaters should be turned off. The sample stage control operates with different control settings at different temperatures. Nominal values for helium operation are described in each of the following sections and summarized in the temperature controller configuration table (TABLE 4-3 and TABLE 4-4). Some adjustments to these settings will be required during operation. Control of the other three stages is generally limited to warming the system for sample exchange. They are most often operated by turning the heater output on and off.

4.5.3 Cooling the Probe Station with Helium

Follow this procedure to cool the sample and radiation shield stages. This procedure assumes the probe station and transfer line are at room temperature and that the vacuum chamber has been evacuated following section 4.4.2.

NOTE

It is tempting to save helium by shutting off flow to the 4 K shield stage, but it is not recommended because the radiation shields would not be cooled. Operating without properly cooled radiation shields will increase base temperature and increase the temperature gradient between the sample and sample stage.

4.5.3.1 Prepare the System

1. Use the z-axis micrometers to raise all probes 3 mm to 4 mm above the sample. Failure to do so will potentially cause damage to the probe tip or scratch the sample surface.
2. Turn off all temperature controller heater outputs or set all control setpoints to 0 K. Both the Model 332 and Model 340 have two control loops.
3. Close the sample stage micrometer valve to establish zero. When you feel a “spongey” stop, the valve is closed; do not over-torque as the valve is delicate.
4. Open the sample stage micrometer valve by opening it counterclockwise six to eight turns.
5. If installed, remove the exhaust valve assembly or open the valve completely.
6. If present, remove any protective cap from the end of the cryogen inlet port on the bayonet.
7. Unscrew the bayonet compression fitting from the port, removing the two metal parts and the o-ring. If the o-ring does not come out, use a finger or the plastic o-ring positioning tool to gently remove the o-ring from the port.
8. Prepare the transfer line by placing the bayonet compression fitting onto the transfer line shoulder (FIGURE 4-13).
9. Close the transfer line foot valve (FIGURE 4-13) to establish zero.
10. Open the transfer line foot valve five turns.
11. Place the ½ in compression fitting (included in the CPX spares kit) on the withdraw leg of the transfer line with the o-ring toward the bottom (the o-ring will hold the fitting on the transfer line).

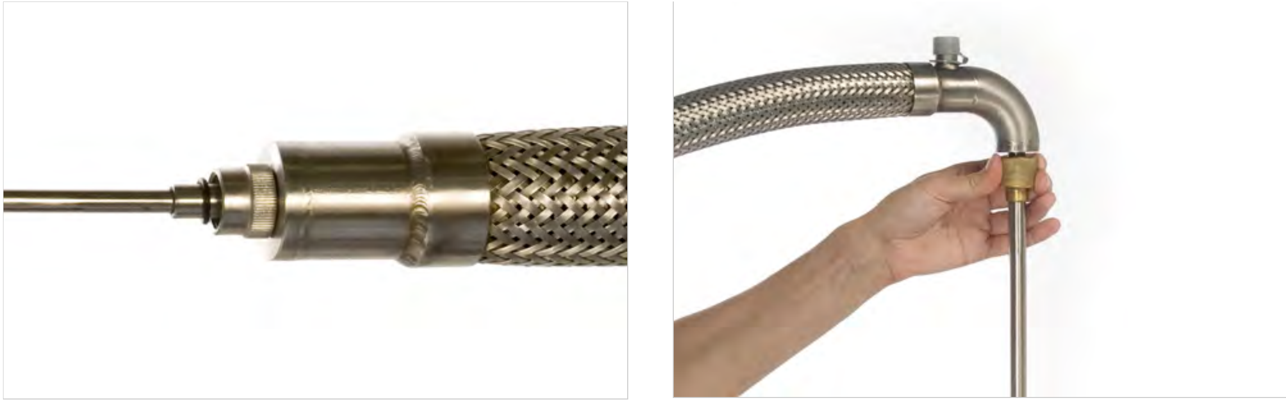


FIGURE 4-13 ***Left: Bayonet compression fitting on the transfer line shoulder; Right: Opening the foot valve***

4.5.3.2 Initiate the Helium Transfer

1. Remove the plug in the Dewar top port (FIGURE 2-9) and slowly open the top withdraw port to relieve the pressure in the Dewar.
2. Lower the transfer line into the Dewar until the pressure just starts to rise (FIGURE 4-14). Thread the ½ in compression fitting onto the top of the Dewar, but do not fully tighten it so that the transfer line can still be inserted further into the Dewar.
3. Close the shut off valve, isolating the low pressure relief valve from the Dewar.

WARNING

The high pressure relief valve should never be closed or disabled.

4. Monitor the pressure and keep it between 48 kPa to 62 kPa (7 to 9 psi). Use the shut off valve on the low pressure relief valve to maintain pressure.
5. Continue to lower the transfer line until the transfer line leg hits the bottom of the Dewar. Do this slowly so that the Dewar pressure does not rise dramatically.
6. Fully tighten the ½ in compression fitting on the Dewar to secure the transfer line.
7. The Dewar pressure should be maintained at approximately 34 kPa (5 psi) for the remainder of the cooldown.
8. Most helium Dewars will not self pressurize at these flow rates, so regulated helium gas pressure must be introduced through the gas port on the Dewar.
9. Allow the transfer line to pre-cool until a continuous plume of white vapor is ejected from the target side leg (FIGURE 4-14, middle). This should take approximately 5 min.
10. Use a clean cloth to wipe any ice crystals from the tip of the transfer line.
11. Immediately after wiping away the ice crystals, quickly insert the transfer line into the bayonet on the probe station (FIGURE 4-14, right). Push the transfer line in until it stops, then hand tighten the bayonet compression fitting.
12. The transfer is started; listen for a whooshing sound at the beginning of the transfer as the liquid cryogen is evaporating in the refrigerator.

FIGURE 4-14 ***Left: Inserting the transfer line into the Dewar; Middle: Plume indicating the process of precooling the transfer line is complete; Right: Inserting the transfer line into the bayonet on the probe station***

4.5.3.3 Allow the Sample and Radiation Shield Stages to Cool

1. Wait for all stages to cool to below 100 K.
2. Close the vacuum isolation valve.

CAUTION

Close the isolation valve when the refrigerator is cold to prevent the chamber from being vented if the pump is accidentally turned off or if the vacuum pump loses power. Venting the chamber when the refrigerator is cold can damage the probe station.

3. Turn off and vent the turbo pump (see section 4.4.3).
4. Allow the stages to cool down. The sample stage should be 4.5 K to 5 K, the 4 K shield stage should be below 5 K, the radiation shield stage should be 15 K to 20 K, and the second shield stage should be less than 50 K.
5. Wait at least 20 min to give the refrigerator and probe arms time to stabilize in temperature before making repeatable measurements. Stabilization occurs approximately 20 min after all refrigerator stages reach base temperature.
6. Reduce helium flow and Dewar pressure to 27 kPa (4 psi) for normal operation. Refer to the following sections for more information on operating the probe station once base temperature is reached.

NOTE

If the system does not cool as expected, refer to troubleshooting information in section 6.3.3.

4.5.4 Operating the Sample Stage from 4.2 K to 6 K

Follow this procedure to operate the sample stage from 4.2 K to 6 K. Because it is difficult for the electronic controller to achieve stable temperature control in this range, temperature is maintained using the mechanical controls. This procedure will also help minimize the consumption of cryogen while in this range, and it assumes that the sample and 4 K shield stages have stabilized below 5 K.

1. Reduce the pressure in the Dewar to 28 kPa (4 psi). This reduces the temperature of the cryogen and makes it easier to regulate flow and temperature of the sample stage.
2. Reduce cryogen flow for best efficiency. To do this, perform the following steps:
    a. Close the transfer line foot valve one half turn; wait 2 min to see if the temperature rises at the 4 K shield stage (channel B on the Model 340 temperature controller) .

b. Repeat step a until you see the temperature at the 4 K shield stage rise to approximately 0.5 K above base temperature.
c. Open the foot valve approximately one quarter turn and wait 1 min to see if the temperature at the 4 K shield stage stops rising.
d. Repeat step c until you see the temperature at the 4 K shield stage stabilizes at approximately 5 K to 10 K.

3. Regulate cryogen flow to the sample stage.

a. Close the sample stage micrometer valve on the probe station one half turn; wait 2 min to see if the temperature rises at the sample stage (channel A on the Model 340 temperature controller).
b. Repeat step a until you see the temperature at the sample stage rise.
c. At this point the sample stage micrometer valve can be used to regulate the sample stage temperature within a range of approximately 1 K to 2 K above base temperature.

4.5.5 Operating the Sample Stage 6 K and Above

Follow this procedure to maintain sample temperature above 6 K. This procedure assumes that you have cooled the refrigerator to base temperature (see section 4.5.3) and wish to bring it up to the temperature your experiment requires. Cooling the system to base temperature stabilizes the temperature of the 4 K shield and radiation shield stages, making it easier to regulate the temperature of the sample stage.

NOTE

It is recommended to keep the radiation shields cold even when raising the sample stage to elevated temperatures to reduce thermal gradients.

It is sometimes difficult to re-cool the sample stage after operating it above 100 K. Please refer to section 5.2.1 if the sample stage cools too slowly.

1. Use the z-axis micrometers to raise all probes 3 mm to 4 mm above the sample.
2. Reduce the pressure on the Dewar to between 21 kPa and 34 kPa (3 to 5 psi). This reduces the temperature of the cryogen and makes it easier to regulate flow and temperature of the sample stage.
3. Reduce cryogen flow for best efficiency. To do this, perform the following steps:

a. Close the transfer line foot valve one half turn; wait 2 min to see if the temperature rises at the 4 K shield stage (channel B on the Model 340).
b. Repeat step a until you see the temperature at the 4 K shield stage rise to approximately 0.5 K above base temperature.
c. Open the foot valve approximately one quarter turn and wait 1 min to see if the temperature at the 4 K shield stage stops rising.
d. Repeat step c until you see the temperature at the 4 K shield stage stabilize at approximately 5 K to 10 K.

4. Close the sample stage micrometer valve completely, then open it as shown in TABLE 4-4. The valve may need to be more open in the beginning if the sample stage needs to cool significantly.
5. Change the setpoint (Model 340, loop 1) to the desired temperature.
6. Use the controller settings given in TABLE 4-4 to set the P, I, and D heater range settings. If the controller is set for zone control mode, these selections will be made automatically.
7. Wait for the temperature at the sample stage to stabilize.
8. Adjust the micrometer valve to achieve a heater power (Model 340, loop 1) consistent with the nominal heater power given in TABLE 4-4.
9. Adjust the P, I and D settings as necessary to improve stability.

4.5.6 Returning to Room Temperature

Follow this procedure to return the probe station to room temperature and to prepare the station for sample exchange.

1. Use the z-axis micrometers to raise all probes up 3 mm to 4 mm above the sample stage.
2. Open the shut-off valve to the low pressure relief valve to reduce the pressure in the Dewar to its lowest pressure.
3. Close the foot valve on the transfer line.

NOTE

Frost buildup on the bayonet may prevent the transfer line from sliding out. The frost can be gently thawed with a heat gun.

4. Warm the sample stage to a setpoint of 290 K by entering the appropriate controller settings given in TABLE 4-3.
5. Warm the 4 K shield stage, radiation shield stage, and second shield stage to a setpoint of 290 K by entering the appropriate controller settings for each stage given in TABLE 4-3.
6. Optional: when all stages in the refrigerator are above 100 K the system can be purged with dry nitrogen gas to speed warm up (section 4.4.4).
7. It is safe to open the vacuum chamber when all refrigerator stages are at their temperature setpoints and the probe arm is above 290 K .
8. If the probe station is not going to be cooled within the next 6 h, do the following:
   a. Raise the transfer line so the bottom of the Dewar-side leg is out of the liquid cryogen in the Dewar but still inside the Dewar.
   b. Open the shut-off valve to the low pressure relief valve on the Dewar. The Dewar pressure will drop.
   c. As the Dewar pressure approaches atmosphere, remove the transfer line from the Dewar and store it where it will not be bent or dropped.
   d. Close the top of the Dewar and leave the low pressure relief valve open.
9. If the probe station is going to be out of service for any length of time:
   a. If the vacuum chamber was opened, reinstall the radiation shield lid and vacuum chamber lid.
   b. Close the purge valve and disconnect the gas line.
   c. Open the vacuum isolation valve.
   d. Turn on the turbo pump for approximately 15 min.
   e. Close the vacuum isolation valve.
   f. Turn off the turbo pump.

4.5.7 Temperature Control Summary

The temperature controller configuration table (TABLE 4-1) and the mechanical and electronic control settings table (TABLE 4-3 and TABLE 4-4) summarize the typical settings needed to maintain CPX temperature control.

	Sensors				Heaters				
	Sensor type	**Temperature controller**	**Input sensor channel**	**Sensor curve**	**Control loop**	**Power limit**	**Resistance**	**Temperature controller rear panel connection**	**Auxiliary amp channel**
Sample stage (stage 1)	Silicon diode	Model 340	A	Calibrated	1	50 W	50 Ω	Banana plug	—
4 K shield stage (stage 2)	Silicon diode	Model 340	B	DT-670	2	100 W	25Ω	BNC	1
Radiation shield (stage 3)	Silicon diode	Model 332	A	DT-670	2	100 W	25 Ω	BNC	2
Shield stage (stage 4)	Silicon diode	Model 332	B	DT-670	1	50 W	50 Ω	Banana plug	—
Probe arm	Platinum	Model 340	C	PT-100/250	—	—	—	—	—

TABLE 4-1 *Temperature controller configuration*

	Model 340 loop 1	Model 340 loop 2	Model 332 loop 1	Model 332 loop 2
Power up?	Off	Off	Disabled	Disabled
Control mode	Manual PID	Manual PID	Closed	Closed
Filter	Off	Off	—	—
Max temperature	475 K	380 K	—	—
Max heater current	1 A	—	—	—
Setpoint ramp	Off	Off	Off	Off

TABLE 4-2 ***Model 332 and 340 initial settings***

		Refrigerator cooldown to 4.2 K	Maintaining sample stage between 4.2 K to 6 K	Sample stage operation below 4.2 K	Operating sample stage 6 K and up	Cooling sample stage with remaining refrigerator cold	Returning refrigerator to room temperature
Mechanical control settings	Foot valve*	5 to 9 turns open	2 turns open	3 to 4 turns open	2 turns open (4 K shield stage 4.3 to 4.4 K)	2 turns open	Closed
	Dewar pressure	34 kPa (5 psi)	28 kPa (4 psi)	28 kPa (4 psi)	28 kPa (4 psi)	28 kPa (4 psi)	6.89 kPa (1 psi)
	Micrometer valve**	6 to 8 turns open	1 to 3 turns	1 to 3 turns	See TABLE 4-4	8 to 10 turns open	6 turns open (leave open)
	Dual valve	Not used	Not used	Open at base temp	Not used	Not used	Not used
	Exhaust valve	Not used	Not used	Not used	Not used	¼ to 1 turn open	Not used
Electronic control settings	**Sample stage**						
	Heater range	Off	Off	Off	See TABLE 4-4	Off	50 W
	Nominal power	—	—	—	See TABLE 4-4	—	100%
	4 K shield stage						
	Heater range	Off	Off	Off	Off	Off	On (100 W)
	Nominal power	—	—	—	—	—	100%
	Shield stage						
	Heater range	Off	Off	Off	Off	Off	On (100 W)
	Nominal power	—	—	—	—	—	100%
	2nd shield stage						
	Heater range	Off	Off	Off	Off	Off	High (50 W)
	Heater range	—	—	—	—	—	100%

**Higher rates of cryogen flow will shorten refrigerator cooldown time at the expense of more cryogen consumption.*
***Do not close the micrometer valve completely as this may cause it to freeze closed.*

TABLE 4-3 ***General mechanical and electronic control settings***

Sample Stage	6 K to 10 K	10 K to 30 K	30 K to 100 K	100 K to 250 K	250 K to 325 K	325 K to 475 K
Micrometer valve	4 to 6 turns open	3 to 5 turns open	3 to 5 turns open	2 to 4 turns open	2 to 4 turns open	1 to 2 turns open
Nominal power	50% at 10 K	15% at 20 K	3% at 50 K	10% at 200 K	40% at 300 K	30% at 400 K
Heater range	500 mW	5 W	50 W	50 W	50 W	50 W
Proportional (P)	250	300	300	175	175	150
Integral (I)	75	50	50	20	15	15
Derivative (D)	0	0	0	0	0	0

TABLE 4-4 ***6 K and up mechanical and electronic control settings for the sample stage***

4.6 Imaging and Probing the Sample

A clear image of the sample is necessary for properly landing the probe tip. Landing the tip with a poor image can result in intermittent contact, scratches on the sample or probe damage. If you cannot obtain a proper image, please refer to section 6.3.4. Lake Shore recommends that you practice imaging the sample and landing probes before cooling the refrigerator.

NOTE **Remember to raise the probes 3 mm to 4 mm above the sample after practicing.**

Each probe type and sample surface behaves slightly differently when landing probes. The instructions below are general guidelines. Lake Shore recommends developing a standard operating procedure for your lab that is optimal for the probes and samples being used (see section 2.6.7). The plan can be developed by repeating steps 5, 6, and 7 in section 4.6.2 until contact resistance measurements are repeatable.

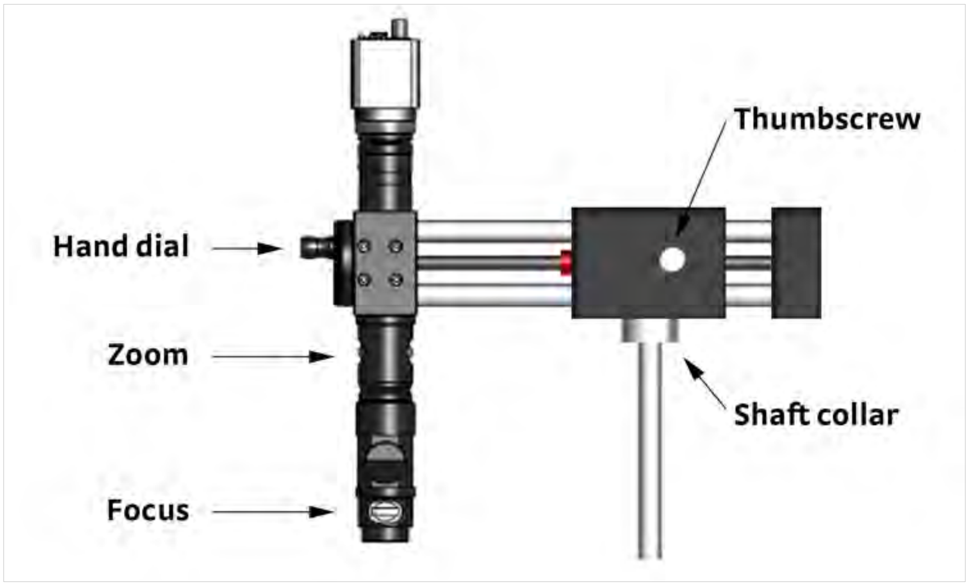


FIGURE 4-15 ***Microscope controls***

4.6.1 Using the Microscope to Image the Sample

Follow this procedure to use the microscope to image the sample.

1. Remove the dust cap from the bottom of the microscope.
2. Loosen the thumbscrew on the vertical microscope shaft, swing the microscope over the center of the viewport, and tighten the thumbscrew. This process is repeated for fine positioning, providing the first axis of motion.
3. Rotate the hand dial until the microscope is over the center of the viewport. This process is repeated for fine positioning, providing the second axis of motion.
4. Turn on the monitor, camera, and light source.
5. Adjust the light source to 50% to begin. As the image is refined, use the least amount of light necessary to view the sample. Turn the light source off during extended measurements to reduce thermal radiation to the sample.
6. Zoom the microscope to its lowest magnification setting to begin. As the image is refined, zoom as necessary to obtain the desired view.
7. Focus must be adjusted repeatedly as the image is zoomed in and further refined. It is necessary to focus clearly on the sample surface in order to properly land probes.
8. The shaft collar is set at Lake Shore for relatively thin samples. If thicker samples are outside of the focal range of the microscope, the shaft collar should be raised.

NOTE

The camera has a specified working distance, which is the distance from the sample to the lens. Raising or lowering the microscope outside this working distance will not improve magnification or resolution.

4.6.2 Landing the Probe

Follow this procedure to manipulate a probe to the sample and make contact.

CAUTION

The sample stage and probe arms should be at a steady temperature before landing a probe. Failure to do so will potentially cause damage to the probe tip or scratch the sample surface.

1. Swing the microscope away from the viewport.
2. Use the z-axis micrometers to raise all probes 3 to 4 mm above the sample. Failure to do so will potentially cause damage to the probe tip or scratch the sample surface.
3. Position the probe tips over the sample or landing pads using the x-axis hand dial and y-axis micrometer.
4. Swing the microscope over the viewport.
5. Adjust the microscope to fill the monitor with the sample image and focus at the height of the landing pads or landing surface.
6. Use the z-axis micrometer to move the probe tip up and down until the tip begins to come into focus. At this point the tip is only 30 µm to 60 µm away from the sample.
7. Continue lowering the probe slowly, stopping to position it as needed so the tip lands on the outside edge of the landing pad.
8. Once it lands on the pad (which is indicated by a forward movement, known as skating), continue lowering it until it skates on the pad by a consistent amount. A typical amount of skating is 20 µm to 25 µm, which is roughly the same as two scale graduations on the z-axis hand dial.
9. The desired position of the probes with respect to the edge of the pads and the desired amount of skating should be determined and used as a lab standard to ensure consistent results.

CAUTION

Raise all probes 3 mm to 4 mm above the sample before changing temperature or vacuum.

4.6.3 Sample Rotation

When landing a microwave probe tip, you may need to rotate the sample stage slightly to align the microwave probe points with the landing pads. To do this, you can use the sample stage rotation hand dial to rotate the sample stage in either direction; turning the hand dial counterclockwise rotates the sample stage clockwise. Fifteen full turns of the hand dial will provide approximately a 5° rotation of the sample stage. This is intended to fine tune the landing of your microwave probe, and is not for major adjustments.

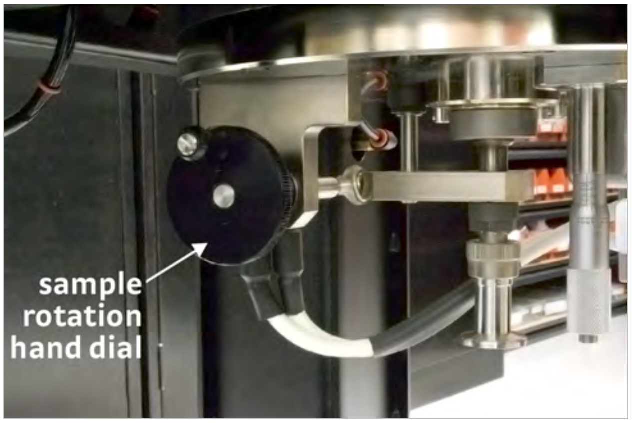


FIGURE 4-16 ***Sample stage rotation hand dial***

4.6.4 Using the Planarization Assembly

There are three points on a GSG microwave probe tip. All three points must be landed on appropriately sized pads for the probe to meet its specified performance. The planarization assembly rotates the probe arm about its x-axis so the three probe points land simultaneously on the sample. Planarization hardware is included on all CPX probe assemblies that were initially configured with microwave cables or probes. Probe assemblies can be upgraded in the field if microwave probes are purchased later. The planarization assembly can be ordered as GSG–TPM. See section 5.3.8 for installation.

We recommend that you planarize the probe on a metallic test substrate prior to evacuating and cooling the system. Gold plated pads are specifically recommended because the following procedure requires landing the probe on the substrate and visually verifying landing marks. Soft gold plating allows the landing marks to be more visible.

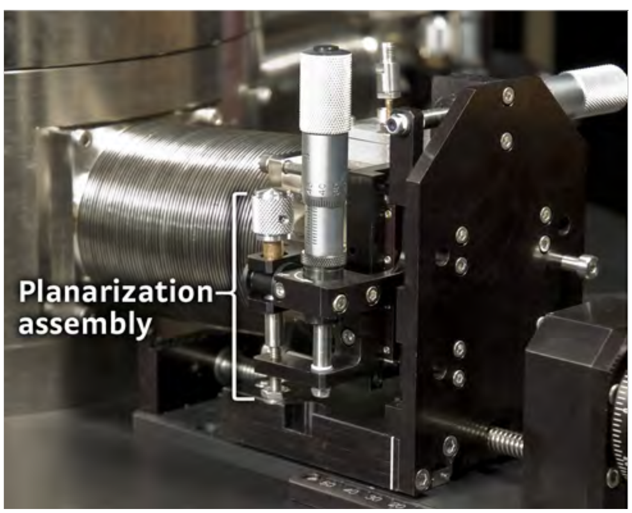


FIGURE 4-17 ***The planarization assembly***

4.6.4.1 Adjusting the Angle of the Planarization Assembly

Follow this procedure to planarize a microwave probe any time it has been serviced or replaced.

1. Use the z-axis micrometers to raise all probes 3 to 4 mm above the sample. Failure to do so will potentially cause damage to the probe tip or scratch the sample surface.
2. Loosen the four long M4 screws holding the bellows flange to the z-axis stage assembly to allow the probe arm base to rotate. Loosen them approximately two to three rotations. Do not remove these screws.
3. Bring the probe close to the surface of the substrate, but do not land the probe.
4. While observing the probe tip through the microscope, turn the differential knob to adjust the angle, as shown in FIGURE 4-18, visually noting the three points' alignment to the x-y plane.

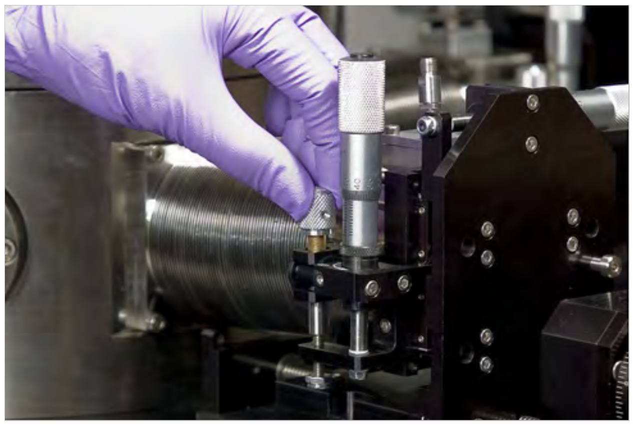


FIGURE 4-18 ***Turn the differential knob to adjust the angle***

5. Check the angle by landing the probe, making contact to a metallic substrate and then raising it again. Marks made by the probe points on the metallization can be seen with the microscope at high magnification.
6. Repeat steps 4 and 5 until the probe points make three uniform marks on the metallization.
7. If the adjustment range of the differential knob is inadequate, the probe must be manually rotated in the probe arm inside the vacuum chamber by loosening the probe arm set screws and manually rotating the probe body. Once the probe has been properly planarized, raise the probe again to avoid damage.
8. Carefully tighten the four M4 screws holding the bellows flange to the z-axis stage assembly. The screws do not need to be tightened securely. They hold these pieces in proper alignment but are not required to seal vacuum.

CAUTION **The four M4 screws holding the bellows flange to the z-axis stage assembly should be installed to a torque of 112 N·mm (16 ozf·in). The torque required is much lower than one might think would be needed. We recommend using a torque wrench to ensure these screws are not over-torqued. If these screws are over-torqued, the z-axis stage and bellows may be damaged.**

9. Check the planarization once more to be sure tightening the bellows' screws did not change the angle.
10. See section 2.5 for more information on making microwave measurements.

Chapter 5: Advanced Operation

5.1 General

This chapter is separated into two parts. Section 5.2 provides advanced operation procedures, building on the knowledge and experience gained performing those operations explained in Chapter 4. Section 5.3 explains reconfiguration procedures that are not typically performed on a day-to-day basis, but which are nonetheless essential to know.

5.2 Advanced Temperature Operation

The material in this chapter is written assuming that the user is an experienced operator of the CPX and understands the theory and operation of the CPX as discussed in Chapter 4.

WARNING

Wear protective gloves when performing the procedures in section 5.2.1 and in section 5.2.2. Various components of the probe station that you need to handle for these procedures will be extremely cold.

5.2.1 Reducing Condensation on the Sample

Even when following good vacuum practices with well maintained equipment, a small amount of residual gas remains in the vacuum chamber after it is evacuated. The residual gas consists primarily of nitrogen and water vapor. It is generally of little concern because it is cryopumped onto the refrigerator when it is cooled with helium. However, problems may occur with some materials if the residual gas condenses on the sample surface.

The following procedure is a simple but effective way to minimize the condensation on the sample. This is accomplished by cooling the 4 K shield stage first so that the majority of residual gas is attracted to it and not the sample.

NOTE

If the sample stage is heated above 100 K and needs to be cooled again, you will need to perform only steps 6 and 7 of this process.

Follow this procedure to reduce condensation on the sample:

1. Evacuate the chamber as described in section 4.4.2.
2. Cycle purge the vacuum chamber using the guidelines in section 4.4.4, but use dry argon instead of nitrogen for this process.
3. Re-evacuate the system to achieve a lower base pressure than achieved initially in step 1.
4. Control the sample stage at 290 K using control settings in TABLE 4-3 and TABLE 4-4 (loop 1 on the Model 340 temperature controller).
5. Cool the refrigerator by following the instructions in section 4.5.3 with the following exception: when instructed to “open the micrometer valve six turns,” (as found in step 4, section 4.5.3.1) open it only two turns. The temperature controller will keep the sample stage warm while the remainder of the refrigerator cools to base temperature. At this point, any residual gas in the chamber will condense on the 4 K shield stage.
6. When the 4 K shield stage is cooled to less than 10 K, open the micrometer valve six turns to begin cooling the sample stage, and turn off the heater. The sample stage will not begin cooling until step 7 is completed.
7. The warm sample stage acts as a flow restriction and will cool very slowly. Force liquid helium into the sample stage to speed up the cooling process. Follow this procedure to do this:

a. Reduce cryogen flow by closing the foot valve until it is 1 to 2 turns open.
b. Locate the exhaust valve assembly and open the valve.
c. Using protective gloves, attach the exhaust valve assembly to the exhaust port on the bayonet using the NW 16 clamp and centering ring included.
d. Close the exhaust valve; then open it approximately one quarter turn. The sample stage will begin to cool more quickly. The 4 K shield stage temperature will rise, but you should not allow it to rise above 20 K. Open the foot valve additional turns if necessary.
e. When the sample stage reaches 100 K, you can open or completely remove the exhaust valve assembly.

8. Operate the probe station normally.

5.2.2 Operating the Sample Stage Down to 2 K

The sample stage of the CPX can be operated below 4.2 K (the boiling point of liquid helium at atmospheric pressure) by decreasing the pressure of the helium flowing to the sample stage and, therefore, reducing its boiling temperature. This process requires the PS-LT option. A vacuum line vibration isolator, PS-PLVI-25 or equivalent, is recommended for vibration sensitive operation.

NOTE **The vacuum turbo pump used to evacuate the vacuum chamber is not suitable for operating the probe station below 4.2 K.**

Follow this procedure to operate the sample stage below 4.2 K.

1. Using the clamp and centering ring provided, install the flexible stainless vacuum line onto the sample stage exhaust port on the bottom of the probe station.
2. Do not attach the other end until step 8.
3. Open the valves on the dual valve assembly completely.
4. Attach the dual valve assembly to the inlet of the PS-LT option vacuum pump.
5. Follow the steps in section 4.5.3 to initiate a helium transfer.
6. Follow the steps in section 4.5.4 to cool the sample stage to 4.2 K while reducing helium consumption.
7. Slowly close the micrometer valve on the probe station until the temperature at the sample stage (channel A on the Model 340 temperature controller) has risen to approximately 4.3 K to 4.5 K. The gas flow coming out of the flexible stainless vacuum line should be minimal at this point.

CAUTION **Flowing too much LHe into the inlet of the PS-LT pump can damage the pump.**

NOTE **Steps 8 to 9 should be done in a quick succession. Failure to perform these in quick succession may cause the sample stage temperature to rise, making the vacuum pump unable to reduce the temperature below 4.2 K.**

8. Using protective gloves, attach the flexible stainless vacuum line to the dual valve assembly.
9. Start the pump and the sample stage temperature will immediately start to drop.
10. Close the sample stage micrometer valve one quarter turn at a time to reduce the temperature to near 2 K.
11. With some experimentation, the micrometer valve can be used to lower the sample stage temperature to the specified 2 K minimum temperature. The goal is to reduce helium flow enough that the pump can maintain low vacuum pressure while still maintaining sufficient cooling capacity.
12. Use the dual valve to regulate temperature between 2 K and 4.2 K.
13. When you are finished with your experiment and no longer need the lower temperature, turn off the pump and quickly disconnect the flexible stainless vacuum line from the dual valve assembly.

5.2.3 Operating with Nitrogen

Most of the instructions in Chapters 4 and 5 are related to operating the probe station using liquid helium. However, most of the instructions can also be applied to operating with nitrogen. The refrigerator is designed to operate with liquid nitrogen down to approximately 78 K. This section describes the significant differences in operating with nitrogen.

Heat Capacity: nitrogen has a lower heat capacity than helium so a higher flow rate is necessary to cool to base temperature (<78 K). This normally requires higher Dewar pressure of approximately 69 kPa (10 psi) and longer cooling time.

Controller Settings: the nominal controller settings given in TABLE 4-3 and TABLE 4-4 are for helium operation. Some experimentation will be necessary to find appropriate settings for nitrogen. It is very difficult for the temperature controller to control below 80 K when using nitrogen. Restricting flow to the sample stage with the micrometer valve normally gives better results.

Cryopumping: nitrogen is less effective at cryopumping than helium. The vacuum chamber may need to be pumped longer to get acceptable results. To help avoid condensation on the sample, it may be necessary to leave the turbo pump running. Operating with LN_2 also affects the vacuum performance of the transfer line, which may need to be pumped out more frequently to maintain acceptable performance.

NOTE **If the probe station is going to be operated or pre-cooled routinely with LN_2 it is beneficial to have a dedicated LN_2 transfer line. The configuration of the transfer may differ based on your specific application. Consult Lake Shore for more information.**

NOTE **It is tempting to save nitrogen by shutting off flow to the 4 K shield stage, but it is not recommended because the radiation shield would not be cooled. Operating without a properly cooled radiation shield will increase base temperature and increase the temperature gradient between the sample and sample stage.**

5.2.3.1 Filling the PS-LN2 Liquid Nitrogen Dewar

This section assumes that the PS-LN2 option has been assembled according to section 3.4.4.5. Familiarize yourself with section 4.5.1 before starting this procedure.

1. Slowly open the vent valve to relieve any pressure in the Dewar. Leave the vent valve open.
2. Attach the liquid port on the PS-LN2 to the LN_2 source with a temporary fill line.
3. Open the liquid valve.
4. Turn on the LN_2 source to initiate filling.
5. Continue filling until the level gauge reads three-quarters full.
6. Turn off the LN_2 source.
7. Remove the fill line from the liquid port.
8. Close the vent valve and liquid valve. The 68 kPa (10 psi) pressure relief valve will maintain safe pressure in the Dewar until the LN_2 is used.

5.2.3.2 Cooling the Probe Station with Nitrogen

Cooling the probe station with nitrogen is nearly identical to cooling with helium. Familiarize yourself with section 4.5.1 for safety information and section 4.5.2 for explanation of the probe station controls.

1. Prepare the system as described in section 4.5.3.1.
2. Initiate a nitrogen transfer using section 4.5.3.2 as a guide. Allow the pressure relief valve to regulate pressure in the Dewar to 68 kPa (10 psi) during this process.
3. Allow the sample stage and 4 K shield stage to cool below 80 K.
4. Reduce Dewar pressure to 34 kPa (5 psi).
5. Leave the turbo pump running during operation.

6. When operation is completed, use section 4.5.6 as a guide to return the system to room temperature.

5.2.3.3 Pre-Cooling with Nitrogen Prior to Helium Transfer

The total amount of helium required to cool the probe station can be reduced if it is pre-cooled with nitrogen first. This process takes at least two hours longer than cooling with helium. This process also creates potential for blockages to form in the transfer line or refrigerator cooling path. If a blockage occurs, the system must be warmed to room temperature before re-cooling.

1. Follow section 5.2.3.2 to begin cooling the probe station with nitrogen.
2. Allow the sample stage and 4 K shield stage to cool below 85 K. This may take approximately two to three hours.
3. Purge nitrogen from the transfer line.
   a. Remove the transfer line from the probe station and nitrogen Dewar.
   b. Use a heat gun to warm both ends of the transfer line and melt the ice.
   c. Wipe both ends of the transfer line dry with a clean cloth.
   d. Insert the withdraw leg of the transfer line a few inches into the helium Dewar and tighten the ½-inch compression fitting. Do not allow the transfer line to contact liquid.
   e. Regulate the helium Dewar to 21 kPa to 28 kPa (3 to 4 psi).
   f. Allow helium gas to flow for several minutes, clearing nitrogen from the transfer line.
4. Purge nitrogen from the refrigerator.
   a. Wait for all stages of the refrigerator to warm to 80 K to 85 K.
   b. Loosen the ½-inch compression fitting.
   c. Finish inserting the withdraw leg of the transfer line into the helium Dewar started in step 3. Check to make sure gas is flowing, but do not wait for a plume to form.
   d. Tighten the ½-inch compression fitting.

NOTE **If gas ceases to flow from the target side of the transfer line, this is an indication that a blockage has occurred. Remove the transfer line from the Dewar and repeat the process starting at 3b above.**

   e. Immediately insert the target leg into the probe station bayonet. The initial flow of helium gas will warm the stages but should clear nitrogen from the refrigerator.
5. Allow the probe station to cool normally with the sample stage micrometer valve open six to eight turns.

NOTE **If either the sample stage or 4 K shield stage do not cool after 10 min to 20 min, an ice blockage has formed in that flow path. The system must be warmed to room temperature and dried before re-cooling. Refer to section 6.3.3.1.**

5.2.4 Operating Sample Stage Above Room Temperature

Some probe station models can be operated above room temperature using inert gas instead of liquid cryogen as a cooling source. Pump the vacuum chamber continuously during this operation to prevent outgassing from contaminating the sample and spoiling the vacuum. A vacuum line vibration isolator, PS-PLVI-40 or equivalent, is recommended for vibration sensitive operation.

CAUTION **Heaters in the CPX should never be turned on when the chamber is not under vacuum, or when the refrigerator is not being actively cooled.**

CAUTION

The maximum temperature for the sample stage is 475 K, the 4 K shield stage is 380 K, the radiation shield and second radiation shield stage is 380 K, and the probe arm is 350 K. Optional probes and sample holders may have lower maximum temperatures. Failure to observe maximum temperatures may result in equipment damage.

CAUTION

The CPX is not designed to be baked out as is common in UHV applications or environments. The sensors and associated wiring will not tolerate the high temperatures involved. See section 6.2.12 for an alternative to baking out.

Follow this procedure to operate the CPX sample stage with inert gas:

1. Thermally anchor all probes to the 4 K shield stage (section 3.5.1).
2. Use the z-axis micrometers to raise all probes 3 mm to 4 mm above the sample. Failure to do so will potentially cause damage to the probe tip or scratch the sample surface.
3. Evacuate the vacuum chamber using the procedure in section 4.4.2.
4. Leave the vacuum isolation valve open and the turbo pump running throughout this process.
5. Close the micrometer valve to establish zero, and then open it counterclockwise and six turns.
6. Install the exhaust valve assembly onto the exhaust port on the bayonet.
7. Close the exhaust valve completely.
8. Insert a 9.5 mm (3⁄8 in) adapter tube into the bayonet.
9. Attach tubing from the adapter tube to the pressure regulator of an inert, dry gas source (helium or nitrogen).
10. Set the gas pressure regulator to approximately 7 kPa to 14 kPa (1 to 2 psi).
11. Turn on the gas flow.

The sample stage can now be heated to the desired temperature using the temperature controller. Some experimentation may be necessary to find the best setting of gas pressure and control settings.

CAUTION

Monitor the 4 K shield stage to ensure that it does not exceed 380 K, or 350 K when using microwave probes.

5.3 Probe Arm Assembly Reconfiguration

The following sections describe the procedures to reconfigure the probe arm assemblies of your probe station. These reconfigurations will not necessarily need to be done daily, but you may find them essential for some research situations.

5.3.1 Installing a Micro-manipulated Translation Stage (MMS-09)

Follow this procedure to add a probe arm stage to your probe station.

1. Use the micrometers and hand dial to center the x, y and z-axis stages in the probe station.
2. Using the 3 mm hex driver, remove the four M4 screws on the arm stage plate if present, and set the plate aside.
3. Using the 2.5 mm hex driver, remove the two M3 screws in the slide insert from the bottom of the new stage (see FIGURE 5-1).
4. Position the slide insert onto the arm stage location so that it is facing as illustrated (FIGURE 5-1) and secure the insert to the arm stage location.

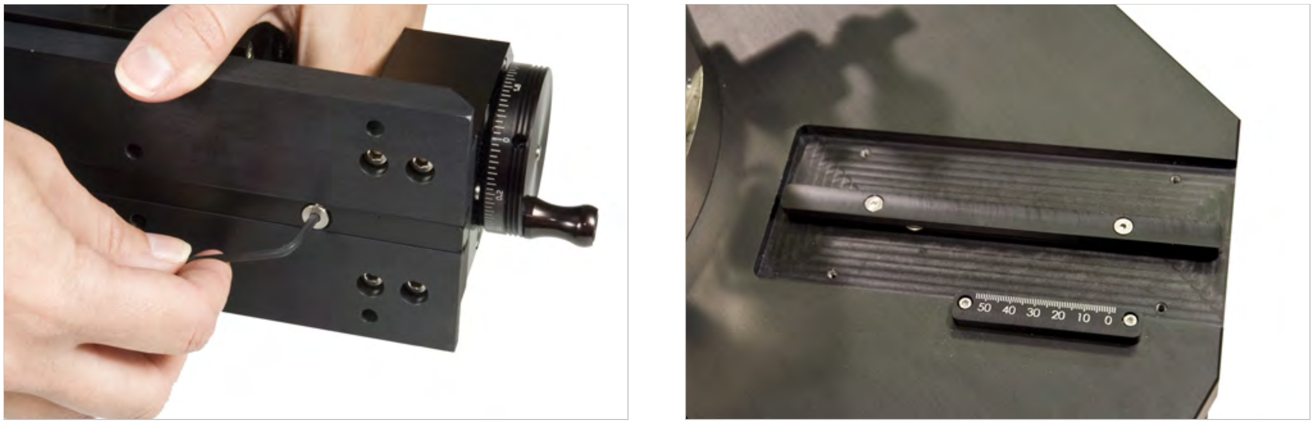


FIGURE 5-1 ***Left: Remove the screws from the slide insert; Right: Secure the slide insert to the arm stage location***

5. Using the 3 mm hex driver, unscrew the four M4 screws from the arm port blank on the vacuum chamber if present. Remove the blank and set it aside.
6. Clean the o-ring groove in the probe arm port (FIGURE 5-2). Clean, inspect and lightly grease the o-ring with vacuum grease and place it in the groove.
7. Slide the stage onto the probe arm location, and carefully guide the cable and probe arm through the arm port (FIGURE 5-2). Take care that the cable and probe arm enter the radiation shield. The copper arm shield braids go between the chamber and radiation shield.
8. Using the 3 mm hex driver, secure the stage to the baseplate with the four M4 screws (FIGURE 5-2).

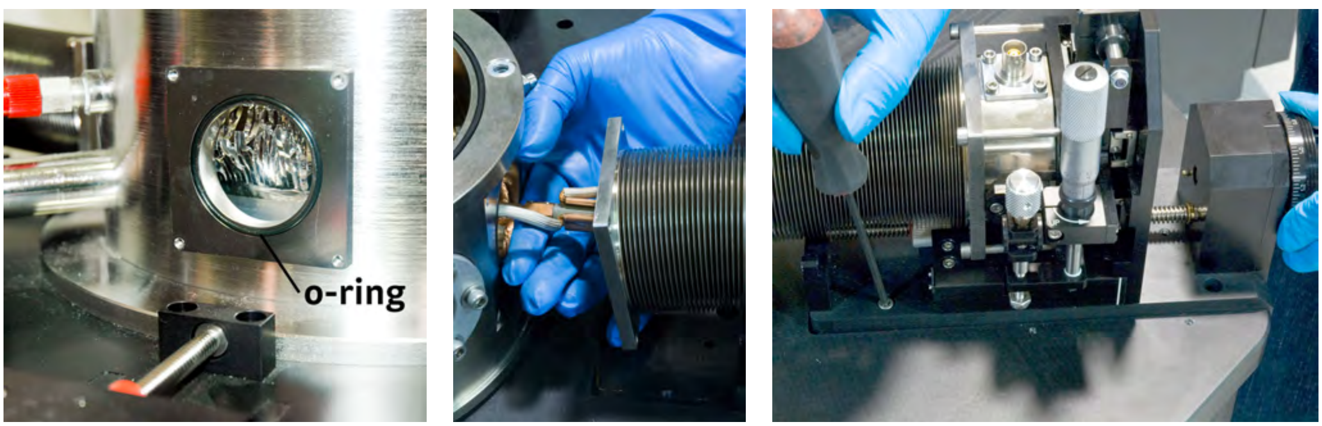


FIGURE 5-2 ***Left: Prepare the o-ring and groove; Middle: Guide the cable and probe arm through the arm port; Right: Secure the stage to the table***

9. Using the 3 mm hex driver, loosen the two bottom screws holding the front of the bellows onto the arm stage and lift the bellows up to align it to the arm port.
10. Using the 3 mm hex driver, attach the bellows to the vacuum chamber. Proceeding in the following manner allows you to maintain equal pressure between the bellows flange and the arm port o-ring seal.

    a. Loosely tighten two of the M4 screws on diagonally opposing sides that attach the bellows to the chamber (FIGURE 5-3).
    b. Loosely tighten the remaining two M4 diagonally opposing screws.
    c. Fully tighten the first two diagonally opposing M4 screws that attach the bellows to the vacuum chamber.
    d. Using the x-axis hand dial, move the probe arm stage forward, toward the vacuum chamber.
    e. Fully tighten the remaining two M4 screws that attach the bellows to the vacuum chamber.

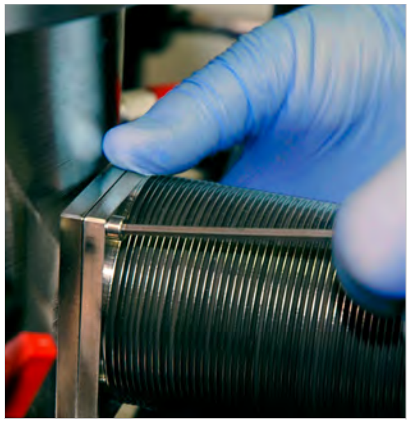


FIGURE 5-3 ***Loosely tighten two M4 screws to begin securing the bellows to the chamber***

11. Attach the arm shield braids to the radiation shield:
    a. Use tweezers to lift an arm shield braid.
    b. Slide the spade lug under the hex screw head and washer (FIGURE 5-4).
    c. Using the 8 mm wrench, tighten the hex screw (FIGURE 5-4).
    d. Use the same procedure to attach the other braid to the other side of the awning.
12. Remove anything temporarily fastening the cable to the end of the probe arm. Take care not to remove the tape that electrically insulates the SMA connector (FIGURE 5-11).

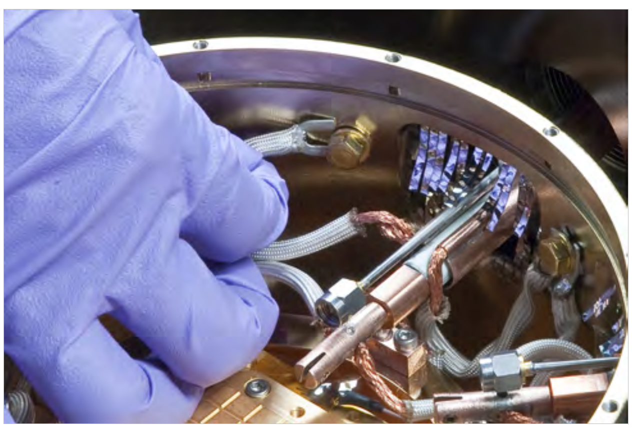
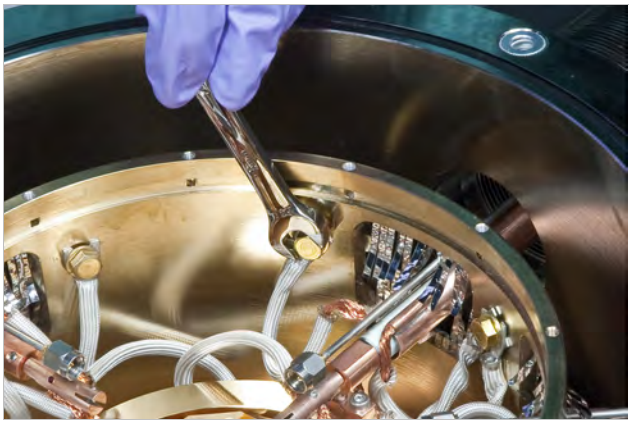


FIGURE 5-4 ***Left: Slide the spade lug under the hex screw head and washer; Right: Tighten the hex screw***

5.3.2 Removing a Micro-manipulated Translation Stage

This section provides directions for removing a micro-manipulated translation stage. Before removing the micro-manipulated translation stage, find a small tray in which to put the hardware removed from the system.

1. Using the x, y and z-axes, center the probe arm in the chamber.
2. To prevent damage to a ZN50 or microwave probe, remove it from the probe arm using the instructions in section 3.5.4 and section 3.5.6 respectively. Do not remove optical fiber probes; they should be left in place.
3. Use an 8 mm wrench to loosen the hex screws that hold the spade lugs at the ends of the arm shield braids to the radiation shield (FIGURE 5-5), but do not fully remove these screws. Slide the spade lugs from under the screw heads and let the arm shield braids fall.



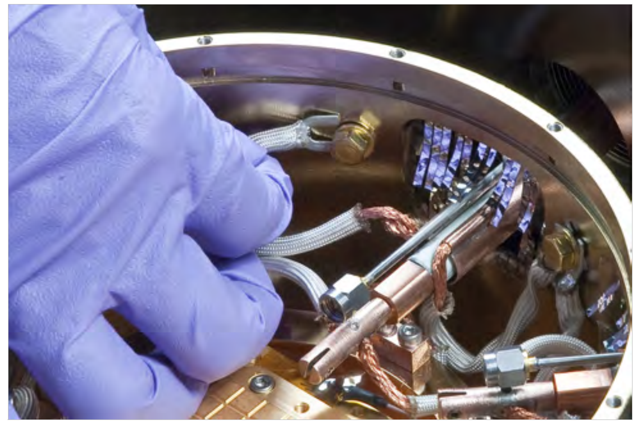
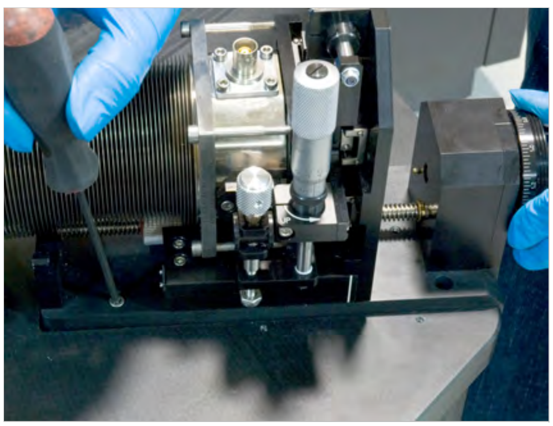
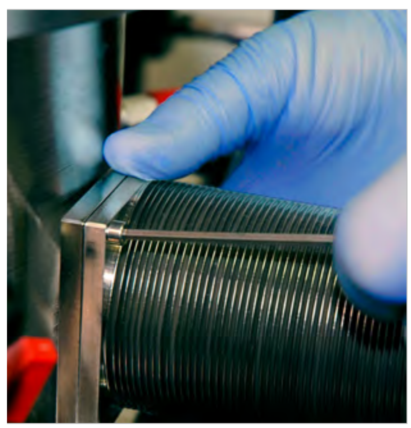


FIGURE 5-5 ***Left and Right: Use a wrench to remove the arm shield braids from the radiation shield***

4. Using the 3 mm hex driver, remove the four M4 screws that attach the stage base to the baseplate (FIGURE 5-6). If necessary, use the x-axis hand dial to move the stage forward to access all of the screws.
5. Using the 3 mm hex driver, detach the bellows from the chamber by removing the four M4 screws (FIGURE 5-6).
6. Supporting the bellows in one hand, carefully pull the probe arm out, guiding the arm shield braids so they do not get stuck on the arm port (FIGURE 5-6).





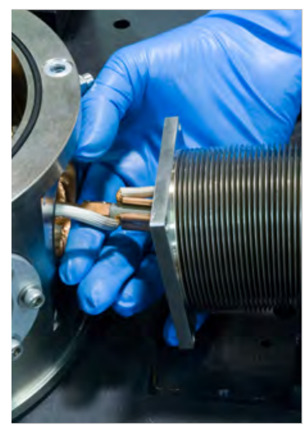


FIGURE 5-6 ***Left: Removing four screws from the stage base; Middle: Detaching the bellows from the chamber; Right: Carefully remove probe arm, cables and thermal anchor from the chamber***

7. Slide the stage back, and use the 3 mm hex driver to secure the stage to its holding location with two M4 screws (FIGURE 5-7). This is an optional step, and is given to provide you with a convenient work space.
8. If another arm is not to be installed in this location, install a blank over the arm port. Do not leave the chamber open to atmosphere.

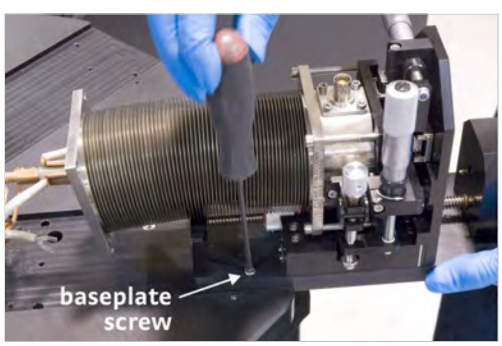


FIGURE 5-7 ***Secure the micro-manipulated stage to its holding location***

5.3.3 Removing a Probe Arm and Base

This procedure assumes that you have removed the micro-manipulated stage and secured the stage to its holding location as directed in section 5.3.2. Follow this procedure to remove a probe arm and base.

1. Using the 3 mm hex driver, loosen the four long M4 horizontal screws that attach the bellows to the z-axis stage (FIGURE 5-8).
2. Grasp the square end flange of the bellows, and with a twisting motion, work the bellows end flange off the probe arm base. This should be done slowly and with a great deal of control.
3. Compress the bellows to make room to slide it carefully off the probe arm. When you reach the end of the probe arm, you will need to tilt it up to remove it from the probe arm (FIGURE 5-8). Place the bellows on a clean, lint-free cloth or wipe.

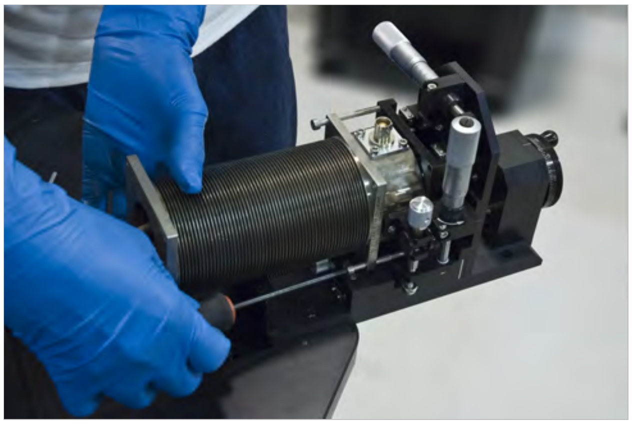
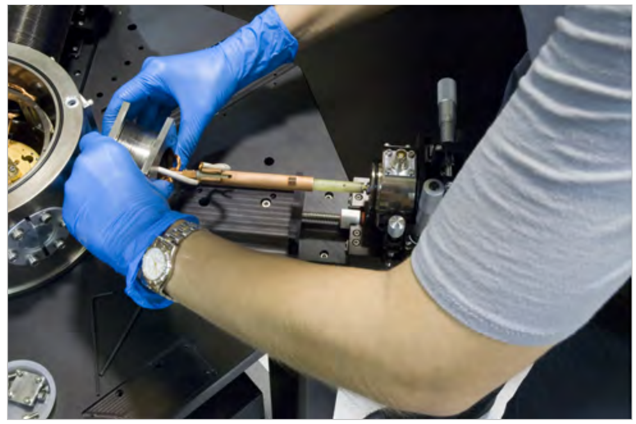



FIGURE 5-8 ***Left: Remove the four horizontal screws that attach the bellows to the z-axis stage; Right: Compress the bellows to remove it from the probe arm***

4. If you have a planarization assembly attached to the probe arm, loosen the two M3 screws that hold the planarization assembly to the arm base. You may need to turn the z-axis micrometer to access the screw that is behind the micrometer (FIGURE 5-9). The planarization assembly will remain attached to the stage.

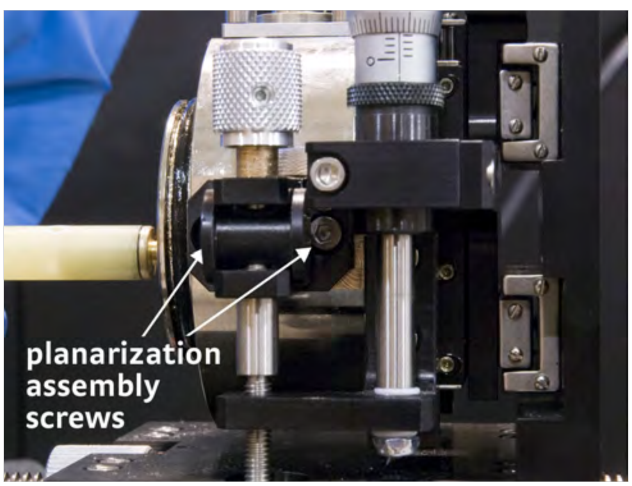


FIGURE 5-9 ***Left: Loosen the two screws holding the planarization assembly to the probe arm base; Right: Pull out the threaded dowels***

5. The probe arm base is loosely secured to the z-axis stage with two stainless steel threaded dowels. Unscrew the threaded dowels, and then pull both dowels out (FIGURE 5-9).

NOTE

Access to the threaded dowels may be to the side of the z-axis stage as shown in FIGURE 5-9 or to the top of the z-axis stage.

6. Lift the probe arm and base off the z-axis stage. Pull the probe arm and base out of the stage.

5.3.4 Installing a Probe Arm and Base

If the probe arm base has not been removed from the stage, remove it using the instructions in section 5.3.3. Then follow this procedure to install a probe arm assembly.

1. Insert the probe arm base into the z-axis stage. Orient the probe arm base as shown in FIGURE 5-10, and hold it in place. Precise alignment is not necessary.
2. Insert the two threaded dowels into the z-axis stage (FIGURE 5-10). Tighten until snug.

NOTE **Access to the threaded dowels may be to the side of the z-axis stage as shown in FIGURE 5-9 or to the top of the z-axis stage.**

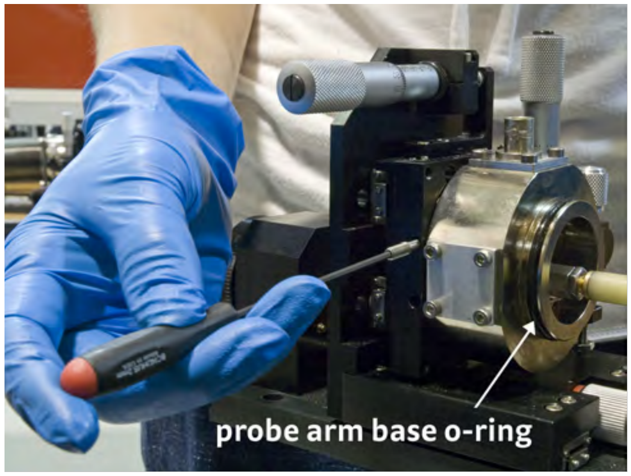


FIGURE 5-10 ***Inserting the threaded dowels into the z-axis stage***

NOTE **The probe arm base is loosely captured by the dowels. It is free to rotate even when you secure the dowels.**

3. If you have a planarization assembly, using the 2.5 mm hex driver, tighten the two M3 screws to secure it to the probe arm base (FIGURE 5-11).
4. If the probe arm has a flexible cable, use a non-residue tape like Kapton® to temporarily tape the cable to the probe arm to easily pull the cable through the bellows. Place the tape near the end of the cable so it can be removed after the assembly is installed (FIGURE 5-11).

FIGURE 5-11 ***Left: Securing the planarization assembly to the probe arm base; Right: Taping the cable to the probe arm***

5. Clean the o-ring groove in the probe arm base (FIGURE 5-10). Clean, inspect and lightly grease the o-ring with vacuum grease and place it in the groove.

6. Place the bellows over the arm; grasp the square end and carefully twist it down until the flange meets the probe arm base (FIGURE 5-12).
7. Install the four long M4 horizontal screws that attach the bellows to the z-axis stage assembly, and tighten the screws evenly (FIGURE 5-12).

CAUTION

The four M4 screws holding the bellows flange to the z-axis stage assembly should be installed to a torque of 112 N·mm (16 ozf·in). The torque required is much lower than one might think would be needed. We recommend using a torque wrench to ensure these screws are not over-torqued. If these screws are over-torqued, the z-axis stage and bellows may be damaged.

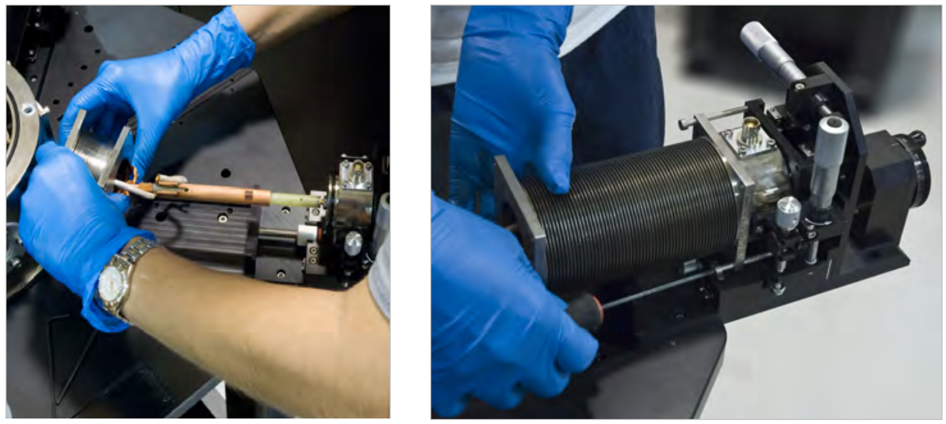


FIGURE 5-12 ***Left: Placing the bellows onto the probe arm base; Right: Attach the bellows to the z-axis stage***

5.3.5 Reconfiguring Ultra-miniature Cryogenic Coaxial Cables

If you will be changing cables frequently, it is recommended to have a probe arm and base available with the appropriate cable already installed, then switch probe arms using the instructions in section 5.3.3 and section 5.3.4. However, if a reconfiguration of the ultra-miniature coaxial cable is necessary, follow this procedure to do so.

5.3.5.1 Removing an Ultra-miniature Cryogenic Coaxial Cable

Ultra-miniature coaxial cables are used with ZN50 probes. Use the following steps to remove an ultra-miniature coaxial cable from a probe arm assembly.

1. Remove the micro-manipulated stage using the instructions in section 5.3.2.
2. Remove the probe arm and base using the instructions in section 5.3.3.
3. Using the 2.5 mm hex driver, remove the four M3 screws that attach the cable feedthrough assembly to the probe arm base (FIGURE 5-13).
4. Lift the cable feedthrough assembly approximately 25 mm (1 in) from the probe arm base and unsolder the cable from the BNC or triaxial connector.
5. At the other end of the cable, grasp the cable near the SMA connector and pull it out of the arm while feeding the loose end into the center of the probe arm.

5.3.5.2 Installing an Ultra-miniature Cryogenic Coaxial Cable

Ultra-miniature coaxial cables are used with ZN50 probes. Use the following steps to install an ultra-miniature coaxial cable onto a probe arm assembly.

1. Clean the o-ring groove of the signal connector feedthrough in the probe arm base. Clean, inspect and lightly grease the o-ring with vacuum grease and place it in the groove (FIGURE 5-13).
2. Insert the end of the coaxial cable without the SMA connector into the hole in the probe arm near the arm shield braids.
3. Push the cable in until it comes to the end. The cable may come out of the exit hole by itself. If not, use small tweezers to pull it out, being careful not to damage the fragile center conductor.

4. Push the wire through the feedthrough opening in the probe arm base (FIGURE 5-13).

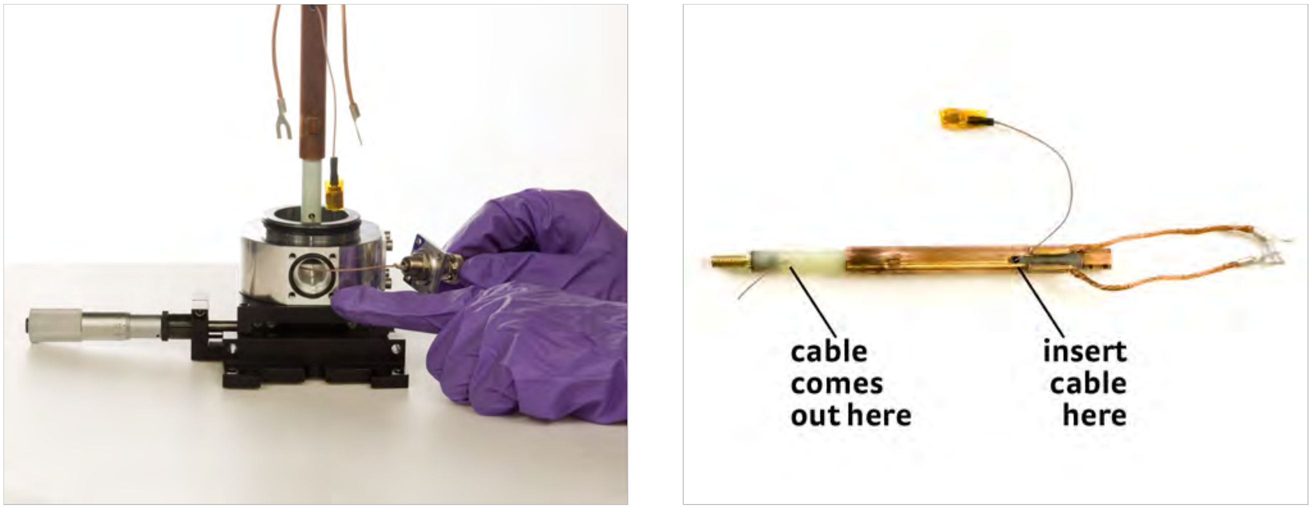


FIGURE 5-13 ***Left: The feedthrough o-ring in the groove; Right: Coaxial cable orientation for inserting into the probe arm base (arm shown off of base for clarity)***

5. With the cable extending approximately 25 mm (1 in) from the probe arm base, solder the cable ends to the BNC or triaxial connector (FIGURE 5-14). The recommended solder is tin-silver (Sn 96% - Ag 4%) with no-clean flux.
6. On either connector type, solder the copper crimped outer conductor to the connector body, and then solder the small center conductor to the center pin. Solder the outer pin first so that the fragile center conductor will not be inadvertently broken off.

CAUTION **Use minimal heat to avoid melting the dielectric between the shield and center conductor.**

7. Test the continuity of the newly soldered arm using section 3.6.5 as a guide.
8. Clean and re-grease the top surface of the o-ring, if necessary.
9. Using the 2.5 mm hex driver, attach the cable feedthrough assembly (FIGURE 5-15, left) to the probe arm base with four M3 screws.

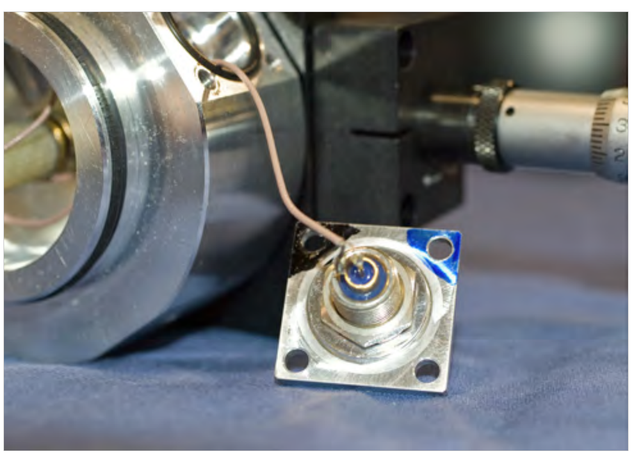


FIGURE 5-14 ***Cable feedthrough assembly***

10. Install the probe arm and base using the steps in section 5.3.4.
11. Install the micro-manipulated stage using the steps in section 5.3.1.
12. Install a ZN50 probe using section 3.5.3.

5.3.6 Reconfiguring Microwave Cables

If you will be changing cables frequently, it is recommended to have a probe arm available with the appropriate cable already installed, then switch probe arms using the instructions in section 5.3.3 and section 5.3.4. However, if a cable change is necessary, you can follow this procedure to do so.

5.3.6.1 Removing a Microwave Cable

Semirigid cables are used with microwave probes. Follow this procedure to remove a semirigid cable from a probe arm assembly.

1. Remove the micro-manipulated stage using the instructions in section 5.3.2.
2. Remove the probe arm and base using the instructions in section 5.3.3.
3. Cut the unwaxed dental floss that ties the cable to the probe arm thermal anchor.
4. Using the 2.5 mm hex driver, remove the four M3 screws that attach the cable feedthrough assembly to the probe arm base (FIGURE 5-15).
5. Pull the cable feedthrough assembly and its attached cable out of the probe arm. The semirigid cable has bends that require some reorientation of the cable feedthrough assembly as the cable is removed.

5.3.6.2 Installing a Microwave Cable

Semirigid cables are used with microwave probes. Follow this procedure to install a semirigid cable onto a probe arm assembly.

1. Clean the o-ring groove of the cable feedthrough in the probe arm base. Clean, inspect and lightly grease the o-ring with vacuum grease and place it in the groove (FIGURE 5-13, left).
2. Carefully insert the cable into the probe arm base. Continue inserting the cable, reorienting the cable feedthrough assembly, until it seats against the probe arm base.
3. Using the 2.5 mm hex driver, attach the cable feedthrough assembly to the probe arm base with four M3 screws. Note that the cable does not pass through the center of the feedthrough assembly (FIGURE 5-15). Rotating this assembly will change the position of the cable end that attaches to the probe (section 5.3.6.3).
4. Test fit a microwave probe onto the probe arm (section 3.5.5). Do not force the threading of the plug if it does not tighten smoothly.
5. If the cable length seems inappropriate, use the instructions in section 5.3.6.3 to adjust the cable length.
6. Remove the microwave probe you used for a test fit.
7. Tie the cable to the probe arm thermal anchor using unwaxed dental floss (FIGURE 3-28).
8. Install the probe arm and base using section 5.3.4.
9. Install the micro-manipulated stage on the probe station using the steps in section 5.3.1.
10. Install a microwave probe using section 3.5.5.

5.3.6.3 Adjusting the Fit of Microwave Cables

An appropriately fitted cable will tighten to the probe connector while the probe arm touches flush or is less than 2 mm from the probe mount. However, there are two situations for which you may need to make adjustments of your semirigid high frequency cables. First, if the connector plug does not smoothly tighten to the probe socket, you will need to make an adjustment. If there is too much tension or misalignment in mating the semirigid cable to the connector, the high frequency connectors may be damaged. Second, if you are able to tighten the connector plug to the probe socket, but there is more than a 2 to 3 mm gap between the probe arm and the probe body, then you will need to make an adjustment.

A few adjustments can be made to change the relative positions of the cables and the probes. These are listed in order of increasing difficulty. The more difficult methods allow for more adjustment range.

First Method: Rotate the Cable Feedthrough Assembly

1. Remove the micro-manipulated stage following the steps in section 5.3.2.
2. Remove the bellows following steps 1 to 2 in section 5.3.3.
3. Remove the four M3 screws holding the cable feedthrough assembly to the probe arm base (FIGURE 5-15).
4. Rotate the feedthrough assembly into position and loosely start the four M3 screws, leaving the cable free to rotate in the feedthrough. The cable does not pass through the center of the feedthrough assembly (FIGURE 5-15). Rotating this assembly changes the position of the cable end that attaches to the probe.

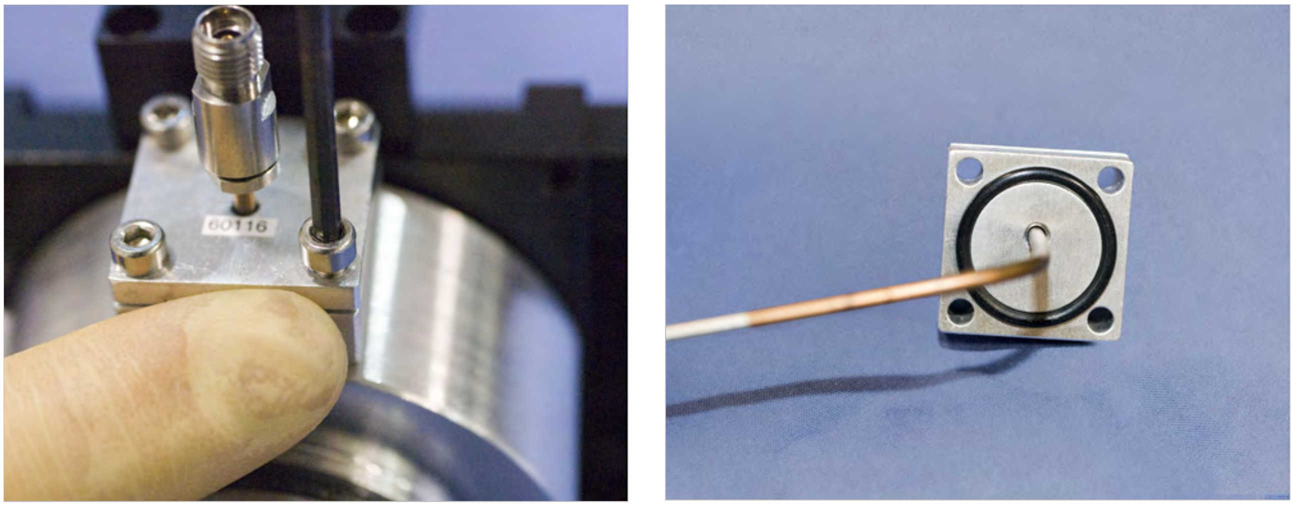


FIGURE 5-15 ***Left: Removing the four M3 screws that hold the feedthrough assembly to the probe arm base; Right: The off-centered hole on the cable feedthrough assembly***

5. Start but do not tighten all four feedthrough assembly screws.
6. Gently push or pull both ends of the cable in the desired direction. The cable should slide through the unwaxed dental floss holding it to the thermal anchor on the probe arm with some gentle wiggling of the probe end.
7. The height of the connector above the feedthrough is not fixed. Set the height necessary to adjust the probe end of the cable to approximately the correct height to mate with a microwave probe.
8. Using the 2.5 mm hex driver, tighten the four M3 screws on the cable feedthrough assembly.
9. Test the fit. If there is not enough adjustment with this method, go to the second method.
10. Install the bellows to the micro-manipulated stage following steps 5 to 7 in section 5.3.4.
11. Install the micro-manipulated stage to the probe station using the instructions in section 5.3.1.

Second Method: Reshape the Microwave Cable

1. Remove the micro-manipulated stage following the steps in section 5.3.2.
2. Remove the probe arm and base using the instructions in section 5.3.3.
3. Remove the cable assembly following the guidelines in section 5.3.6.1.
4. By hand, carefully reposition the 90° bend in the cable to give or take length from the vertical section and add or subtract it from the horizontal section. Keep pressure on the inside radius as the bend is made to prevent the cable from kinking.
5. Install the cable assembly using the instructions in section 5.3.6.2. You may need to use the first method of this section for a final adjustment.

6. Test the fit. If there is not enough adjustment with this method, go to the third method.
7. Install the probe arm and base to the micro-manipulated stage using the instructions in section 5.3.4.
8. Install the micro-manipulated stage to the probe station using the instructions in section 5.3.1.

Third Method: Adjust the Arm Length

1. Remove the micro-manipulated stage following the instructions in section 5.3.2.
2. Remove the probe arm and base using the instructions in section 5.3.3.
3. Remove the cable assembly using the instructions in section 5.3.6.1.
4. For the probe arm that has the temperature sensor, remove the 6-pin feedthrough receptacle using section 5.3.5.1 as a guideline. Mark the four sensor wires so that they can be replaced in their original pin locations.
5. Using a 10 mm wrench, loosen the locknut located on the end of the probe arm nearest the probe arm base.
6. Rotate the probe arm in full revolutions to lengthen or shorten it as necessary.
7. Tighten the locknut while keeping the probe arm oriented properly.
8. For the probe arm that has the temperature sensor, replace the 6-pin feedthrough receptacle using section 5.3.5.2 as a guideline. Replace all four wires in their original locations.
9. Install the cable assembly using the instructions in section 5.3.6.2.
10. Install the probe arm and base using the instructions in section 5.3.4.
11. Install the micro-manipulated stage using the instructions in section 5.3.1.

5.3.7 Reconfiguring an Optical Fiber Assembly

If you will be changing cables frequently, it is recommended to have a probe arm available with the appropriate cable already installed, then switch probe arms using the instructions in section 5.3.3 and section 5.3.4. However, if an optical fiber change is necessary, you can follow this procedure to do so.

5.3.7.1 Removing an Optical Fiber

The optical fiber assembly includes the optical fiber, terminations and the feedthroughs. Follow this to remove an optical fiber from a probe arm and base.

1. Remove the micro-manipulated stage using the instructions in section 5.3.2.
2. Remove the bellows following steps 1 to 2 in section 5.3.3.
3. Cut the unwaxed dental floss that ties the optical fiber to the probe arm thermal anchor.
4. Using the 2.5 mm hex driver, remove the four M3 screws that attach the fiber feedthrough to the feedthrough extension.
5. Using the 2.5 mm hex driver, loosen the M3 set screw on the probe mount to release the optical fiber tip (FIGURE 5-19).
6. Pull the feedthrough and its attached optical fiber out of the probe arm. Handle the fragile optical fiber carefully; it should not be bent sharply or it may break.
7. If you are changing probe types, remove the feedthrough extension and probe mount as necessary.

5.3.7.2 Installing an Optical Fiber Assembly

The optical fiber assembly includes the optical fiber, terminations and feedthroughs. To remove the optical fiber, reference section 5.3.7.1. Follow this procedure to install an optical fiber assembly onto a probe arm assembly. The procedure includes steps for installing the optical fiber probe mount.

1. Orient the probe mount so the probe mount braids and braid blockare down.
2. Slide the dowel end of the probe mount all the way into the probe arm. The brass body of the probe mount should touch the copper end of the probe arm.
3. Using the 1.5 mm hex driver, secure the probe mount to the probe arm by tightening the probe arm set screws (FIGURE 5-16).

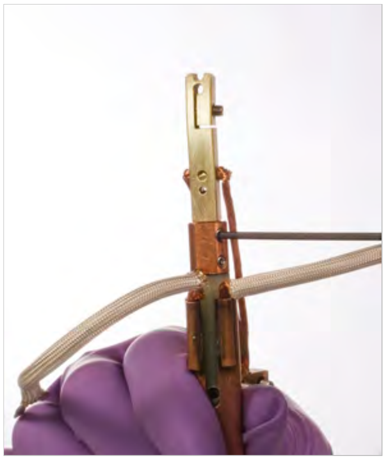


FIGURE 5-16 ***Secure the probe mount to the probe arm***

4. Lightly grease the feedthrough o-ring (FIGURE 5-17) and place it in the groove.
5. Using the 2.5 mm hex driver, attach the feedthrough extension to the probe arm base with four M3 screws (FIGURE 5-17).
6. Lightly grease the extension o-ring, and place it in the groove.

NOTE **Do not loosen the nut between the cable and the flange (FIGURE 5-17).**

FIGURE 5-17 ***Left: Attaching the feedthrough extension to the probe arm base; Right: The nut between the cable and the flange—SMA style shown***

7. If there is any cellophane tape on the optical fiber, remove it.
8. Insert the optical fiber tip into the feedthrough extension (FIGURE 5-18). Handle the fragile optical fiber carefully; it should not be bent sharply or it may break. Pull the cable through until the feedthrough seats against the feedthrough extension.
9. Using the 2.5 mm hex driver, attach the feedthrough to the feedthrough extension with four M3 screws.

FIGURE 5-18 ***Insert the optical fiber tip into the feedthrough extension***

10. Loosely wrap the fiber around the probe arm to take up any slack.
11. Insert the optical fiber tip into the opening in the probe mount (FIGURE 5-19).
12. Using the 2.5 mm hex driver, secure the tip by gently tightening the M3 screw (FIGURE 5-19).

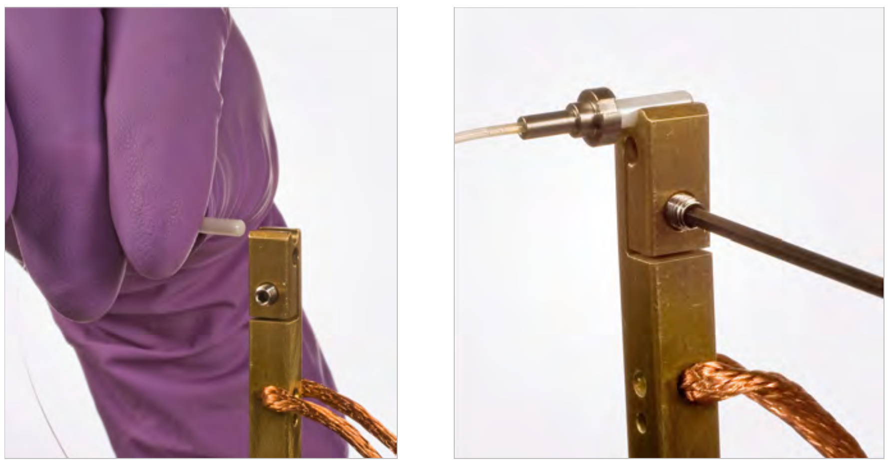


FIGURE 5-19 ***Left: Inserting the optical fiber tip into the opening in the probe mount; Right: Securing the optical fiber tip by tightening the M3 screw***

13. Using unwaxed dental floss, tie the fiber to the arm to keep it from unraveling during use (FIGURE 5-20).

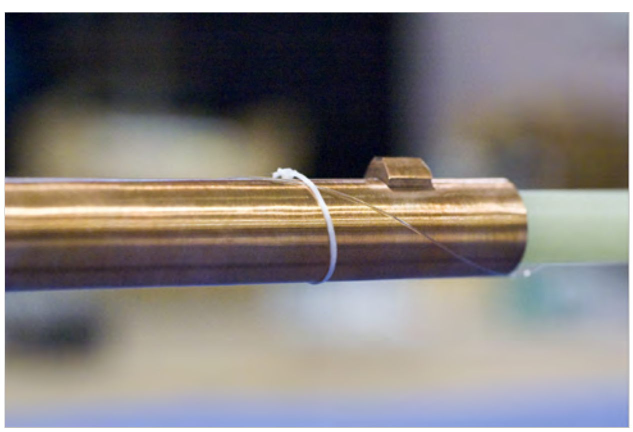


FIGURE 5-20 ***Tie the optical fiber to the arm***

14. Install the probe arm and base using section 5.3.4.
15. Install the micro-manipulated stage using section 5.3.1.
16. Attach the braid block following step 5, a–c in section 3.5.3.1
17. Before initiating a cryogen transfer, test probe arm reach. It is very costly and time consuming to initiate cooldown only to find the probe mount braids prevent full probe travel.

5.3.8 Installing the Planarization Assembly

You will need to install the planarization assembly if the micro-manipulated stage was not configured with one, and you intend to use microwave probes. The planarization assembly allows the microwave probe to be rotated so that all three points on the microwave probe tip touch the sample at the same z-axis position.

Follow this procedure to install the planarization assembly. This section assumes that you have removed any probe from the selected stage to prevent damage to the probe. The micro-manipulated stage does not need to be removed for this operation.

1. Center the probe arm with the y-axis micrometer, and raise the probe arm fully using the z-axis micrometer. This allows access to the mounting holes in the side of the probe arm base
2. Using the 3 mm hex driver, loosen the four long M4 horizontal screws that attach the bellows to the z-axis stage, so the probe arm base can rotate (FIGURE 5-21). Simply loosen them two to three rotations; do not remove them.

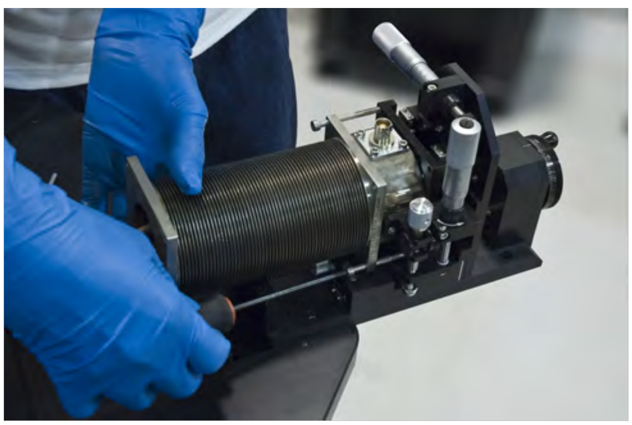


FIGURE 5-21 ***Loosening the four M4 horizontal screws***

3. Remove the lock nut from the end of the planarization assembly.
4. With the mounting holes on the planarization assembly bracket facing the mounting holes on the probe arm base, thread the shaft through the hole for the planarization assembly shaft (FIGURE 5-22).
5. When the mounting holes in the bracket are aligned with the mounting holes on the probe arm base, use the 2.5 mm hex driver to attach the planarization assembly with the two M3 screws provided (FIGURE 5-22).

FIGURE 5-22 ***Left: Thread the shaft through its mounting hole; Right: Attach the planarization assembly to the probe arm base***

6. Using small pliers or an adjustable wrench, thread the nut onto the bottom of the shaft until the end of the shaft is flush with the nut (FIGURE 5-23).
7. Adjust the planarization assembly from end to end to test the installation.
8. Carefully tighten the four long M4 horizontal screws that attach the bellows to the z-axis stage assembly, and tighten the screws evenly (FIGURE 5-12).

CAUTION

The four M4 screws holding the bellows flange to the z-axis stage assembly should be installed to a torque of 112 N·mm (16 in·ounces). The torque required is much lower than one might think would be needed. We recommend using a torque wrench to ensure these screws are not over-torqued. If these screws are over-torqued, the z-axis stage and bellows may be damaged.

FIGURE 5-23 ***Left: Thread the nut onto the bottom of the shaft; Right: Tighten the four long horizontal M4 screws***

Chapter 6: Maintenance and Troubleshooting

6.1 General

This chapter covers maintenance, troubleshooting and field service instructions. Instructions for contacting Lake Shore and arranging product service are in section 6.5.

6.2 Maintenance

This section includes both a preventive maintenance schedule and maintenance instructions, unless those instructions are included elsewhere in this manual.

CAUTION

During all chamber cleaning procedures, wear nitrile gloves to create a biological barrier between your hands and the inside of the vacuum chamber. Failure to comply will result in poor probe station performance.

6.2.1 Preventive Maintenance Schedule

Use this table as a foundation in developing a time table for probe station component maintenance. Tailor the schedule to fit your own probe station use.

Maintenance	Every use	3 months	6 months	12 months	As needed
Maintain a safe, clean work space	×				
Clean the top surface of the sample holder	×				
Inspect for condensation during cooling	×				
Observe changes in cooling behavior	×				
Close and evacuate the vacuum chamber when finished	×				
Clean the inside of the vacuum chamber		×			
Clean the sample holder		×			
Pump out the chamber overnight or over the weekend		×			
Clean BeCu probe tips			×		
Tighten probe arm components			×		
Pump out the transfer line				×	
Change the tip seals of the scroll pump (PSV81-DP)				×	
Clean microwave probes					×
Lubricate micrometer valve o-rings					×
Lubricate chamber lid and probe arm o-rings					×
Clean the viewport windows					×
Clean the vacuum chamber exterior					×

TABLE 6-1 *Preventive maintenance schedule*

6.2.2 Cleaning the Vacuum Chamber Exterior

The exterior of the probe station chamber should be kept generally clean and clear of dust and other possible contaminants. Surfaces may be wiped down using damp, lint-free cloths like Kimwipes®. Isopropyl alcohol on a lint-free cloth is recommended to loosen adhesives and other residue. Dust on the exterior may also be removed with a commercially available compressed air product such as Dust Off®.

6.2.3 Cleaning the Vacuum Chamber Interior

Failure to keep the chamber clean and store it under vacuum will result in poor probe station performance due to contaminants and moisture in the chamber. A dirty chamber requires longer pump down times, more helium to cool and results in higher base temperatures. If the CPX chamber is not properly maintained, it will be increasingly difficult to operate the 4 K shield stage below 5 K.

1. Prior to cleaning, remove the following:
   - Vacuum chamber lid
   - Radiation shield lid
   - Main chamber o-ring
   - Sample holder
   - Probes
2. Wipe down the following surfaces with a lint-free wipe like Kimwipes® and isopropyl alcohol. Do not clean the viewports during this step.
   - Top edge of the radiation shield (mating surface)
   - Mating surfaces of the radiation shield lid
   - Any surface that shows fingerprints
   - Any surface likely touched during sample exchange
   - Sealing surface of the vacuum chamber lid
   - Main chamber o-ring
   - Main chamber o-ring groove

CAUTION

The radiation curtains are very fragile; do not soak them or rub them as they can come off or break.

3. Clean and lubricate the chamber components:
   - Clean the viewport windows (section 6.2.4)
   - Lubricate the main chamber o-rings with a thin layer of high quality vacuum grease (section 6.2.5)
   - Clean the sample holder (section 6.2.6)
4. Reassemble the probe station:
   - Sample holder
   - Probes
   - Main chamber o-ring
   - Radiation shield lid
   - Vacuum chamber lid
5. Pull vacuum for 30 min prior to loading a sample.

NOTE

To minimize the risk of contamination, the radiation shield lid and vacuum chamber lid should remain in place except when working in the chamber. Lake Shore also recommends that you store the chamber under vacuum to reduce oxidation.

6.2.4 Viewport Window Maintenance

Viewport windows require extra consideration. It is important to protect the optics as they are your only way to view and photograph the activity on the sample holder.

6.2.4.1 Cleaning the Viewport Windows

The viewport windows on the radiation shield lids and vacuum chamber lid will need cleaning, as they collect debris and smudges during normal operation. Use cleaners recommended for glass optics. A suggested cleaner is Eclipse® High Purity Cleaning Fluid, available through Edmund Optics.

CAUTION

Never use household cleaners on the optics windows; some optics may be damaged by the chemicals in these cleaners.

6.2.4.2 De-fogging the Viewport Windows

Some condensation on the *outside* of the viewport windows is normal; however, if there is condensation on the inside of the viewport windows, refer to section 6.3.1. When the outside of the viewport window develops condensation during low temperature operation, it is an indication that it needs to be treated with anti-fog solution. A suggested anti-fog solution is Parker's™ Perfect anti-fogging solution, available through Edmunds Optics.

Follow this procedure to de-fog the viewport windows.

1. Apply anti-fog solution to a small, folded, optical cloth.
2. Wipe onto the surface of the viewport using a circular and overlapping motion.
3. Allow the solution to dry until a slight haze appears.
4. Apply a second coat using a new cloth and fresh solution to ensure complete and uniform coverage.
5. Remove the final haze with a clean, dry cotton cloth.

6.2.5 O-Ring Maintenance

O-rings are generally reliable and require very little maintenance. Periodic cleaning and re-greasing is all that is necessary under most circumstances. This is especially true of the vacuum chamber lid o-ring that is located where it can be contaminated with debris. Other o-rings will require routine maintenance only if their seal is broken regularly to reconfigure the probe station.

6.2.5.1 Re-greasing O-Rings

Follow this procedure to re-grease o-rings. Wear nitrile gloves during this procedure.

1. Remove the o-ring using the plastic o-ring removal tool provided in the tool kit.
2. Clean off any old grease with a lint-free wipe and isopropyl alcohol.
3. Clean the o-ring groove and mating surface with a lint-free wipe and isopropyl alcohol.
4. Inspect for small cuts or nicks; replace immediately if found.
5. Inspect for excessive flattening, replace immediately if found.
6. Place a small amount of high quality vacuum grease, such as Apiezon® N grease on one (gloved) finger.
7. Run the o-ring through your fingers until the entire surface is lightly coated.
8. Remove any excess grease.
9. Replace the o-ring in the o-ring groove; do not allow the o-ring to twist in the groove.

6.2.5.2 Accessing Other O-Rings

The o-ring on the vacuum chamber lid is easy to locate. This section describes the location of the other o-rings in the system if you need to access them for maintenance or service.

Viewport window: the viewport window is sealed to the vacuum chamber lid with an o-ring.

Bellows: there is an o-ring sealing each end of each bellows. They can be accessed by following the instructions in section 5.3.2 and section 5.3.3.

Signal connector feedthrough: there is an o-ring between each signal connector feedthrough and its probe arm base. It can be accessed using the instructions in section 5.3.5 as a guide.

Probe arm temperature feedthrough: there is an o-ring between the probe arm base and the 6-pin feedthrough used for the probe arm temperature sensor. This port will be blanked off if there is not a sensor on the arm. It can be accessed using instructions in section 5.3.6.3 (third method) as a guide.

Vacuum chamber ports: the NW 40 and NW 25 gauge ports, the load lock port and the high vacuuum port on the CPX chamber each have an o-ring sealing the blank-off flange to the chamber.

Vacuum chamber base: there is an o-ring sealing the vacuum chamber to its base. Accessing this o-ring requires dropping the refrigerator out of the vacuum chamber. This operation is not recommended for routine maintenance. Please contact Lake Shore service before attempting to drop the refrigerator if you suspect a leak.

Vacuum chamber base feedthroughs: there are a number of electrical and mechanical feedthroughs located on the base of the vacuum chamber and each contains an o-ring. The seals on these feedthroughs are not normally broken during reconfiguration of the probe station. Please contact Lake Shore service before attempting to service these o-rings if you suspect a leak.

6.2.6 Cleaning the Sample Holder

We recommend cleaning sample holders between uses to ensure samples make good thermal contact. Considering the many possible methods used to mount samples onto the sample holders, a variety of methods are necessary to clean them.

Chemical solvents are recommended over mechanical removal methods. The gold plating on the top surface of many sample holders is delicate and will not hold up to abrasives, scrubbing or scratching. Follow the manufacturer's recommendations for removing sample mounting materials such as photoresist.

Be sure that all chemicals are compatible with the materials in the sample holder. Most solvents and removers are compatible with the copper and gold grounded sample holders. Coaxial and triaxial sample holders also contain Kapton® and solder. Isolated sample holders use sapphire.

WARNING

Only work with volatile or toxic chemicals (xylene, acetone, etc.) in a well ventilated area or under a fume hood.

To remove the sample mounting material:

- Apiezon® N grease can be removed using xylene with an isopropyl alcohol rinse
- Silver paint can be removed by soaking in acetone

- VGE-7031 varnish can be removed using equal parts ethanol and toluene

After removing the mounting material, wipe with a lint-free cloth to remove any solvent residue. Finish with an isopropyl alcohol rinse.

6.2.7 Cleaning BeCu Probe Tips

Probe tips made of beryllium copper (BECU in the part number) have a normal shelf-life of about one month before they develop an oxide layer which may impede good electrical contact. If discoloration of the tips or a change in electrical properties becomes noticeable, use the following procedure to clean the tips. Tungsten and Paliney 7 are less prone to oxidation, so they will not need regular cleaning.

We suggest using Tarn-X®, a liquid tarnish remover commonly available in the United States.

CAUTION

The probe tips are very delicate. Do not touch them during this procedure. Failure to comply may result in damaged or broken probe tips.

Follow this procedure to clean BeCu probe tips.

1. Wearing gloves, remove the probe from the probe arm.
2. Place a small drip cup under the probe tip.
3. Wearing gloves, dispense one full-strength drop of liquid tarnish remover just above the probe tip, letting the cleaner run down the tip and into the drip cup (FIGURE 6-1). Do not allow the cleaner to contact any part of the probe body.

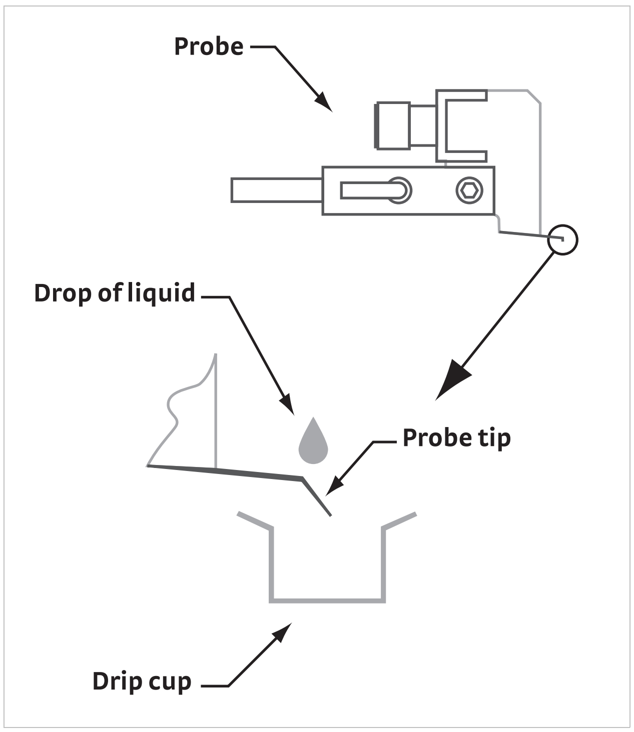


FIGURE 6-1 ***Method for cleaning probe tips***

4. For heavily oxidized probe tips, repeat step 3 as necessary.
5. Within 30 s, drip three or four drops of deionized or distilled water applied in the same manner to rinse the probe tip clean.
6. Rinse with three or four drops of isopropyl alcohol.
7. Allow the probe to dry thoroughly before use.
8. Reinstall the probe.

6.2.8 Cleaning Microwave Probe Points

The points on microwave tips are extremely delicate and require great care in both handling and cleaning.

6.2.8.1 General Cleaning

1. Immerse the probe tip only in a bath of isopropyl alcohol or acetone in an ultra-sonic cleaner.
2. Cycle the ultrasonic cleaner on and off in very short bursts several times. If you do not have an ultrasonic cleaner, simply dip the tip into a bath of acetone.
3. Finish with a rinse in isopropyl alcohol.
4. Allow the probe to air dry thoroughly for several hours (preferably overnight) before use so that no liquid remains within the air gap between the points, or a short will result.

CAUTION

Never use high velocity compressed air directly on the probe tip; the nozzle must be kept 10 in to 12 in away if used. Do not use a brush or cotton swab to wipe the probe tip.

6.2.8.2 Removing Oxidation

1. Tape a piece of clean card stock or heavy paper onto the sample holder.
2. Touch the probe down on the paper slightly so that the ground points begin to flex and slowly drag the probe backward across the paper a distance of 1 mm.

CAUTION

Do not drive the tip forward into the paper, or you will damage the points.

3. In severe cases, touch the probe tips down onto a piece of smooth ceramic and drag the probe backwards 1 mm.

NOTE

This process quickly removes the oxide, but also removes some of the tip material and can result in reduced probe life.

4. After removing oxidation, clean the probe as described in section 6.2.8.1.

6.2.9 Probe Arm Maintenance

The probe arms and stages require very little maintenance; however, some of the fasteners do need to be re-tightened periodically due to thermal cycling or repeated movement. Fasteners associated with thermal interfaces, electrical conduction and mechanical stability should be checked regularly. The instructions for re-tightening these components are the same as those for installation or operation so they are not repeated here.

Tightening the braid block: please reference step 5 in section 3.5.3.1 if you need to tighten a braid block.

Tightening the probe mount: please reference step 4 in section 3.5.3.1.

Tightening the arm shield braids: please reference FIGURE 5-4 in section 5.3.1.

Tightening the probe arm into the probe arm base: follow this procedure to tighten the probe arm.

1. Remove the micro-manipulated stage using the instructions in section 5.3.2.
2. Remove the probe arm and base using the instructions in section 5.3.3.
3. Using the 10 mm wrench, tighten the locknut that secures the threaded brass anchor of the probe arm to the hex standoff of the probe arm base while keeping the probe arm oriented properly.
4. Install the probe arm and base using the instructions in section 5.3.4.
5. Install the micro-manipulated stage using the instructions in section 5.3.1.

6.2.10 Vacuum Pump Maintenance

It is difficult to give specific instructions for all possible combinations of pumps that may be used with the CPX. Refer to the information included with your selected vacuum pump for specific maintenance instructions, and add them to the preventive maintenance schedule in section 6.2.1 of this manual. Some general guidelines on vacuum pump maintenance follow.

6.2.10.1 Turbo Pumps

Turbo pumps are generally considered maintenance-free, and contain no user-serviceable parts or maintenance items. Operate them according to manufacturer's instructions for the longest possible service life.

6.2.10.2 Scroll Pumps

Scroll pumps are frequently used because the fore pump for the turbo pump has replaceable seals called tips that wear with use. As the tips wear, pump performance degrades, but this seldom causes pump failure. The tips should be replaced when the pump no longer performs adequately. Some manufacturers recommend replacing the tips every year (depending on use) to keep the pump operating to specification. However, a scroll pump can still be adequate for use as a fore pump even when it is performing well below its specification.

6.2.10.3 Rotary-Vane Pumps

Rotary-vane pumps are often used as the fore pump for turbo pumps, or to pump on the helium exhaust port as part of a low temperature option. These pumps contain oil, and therefore require routine maintenance.

The oil level in a rotary-vane pump should be checked at least every three months. Insufficient oil will cause catastrophic failure of the pump. If the oil level is low, add only the type of oil recommended by the pump manufacturer. Do not overfill the oil reservoir. Overfilling may cause oil to exhaust from the pump or shorten the service life of the pump.

The oil in a rotary-vane pump should be changed regularly. The time between changes varies based on hours of use and the type of gases being pumped. The oil itself can be an indicator of when it needs to be changed. The oil turns darker with use and should be changed when it becomes noticeably darker than new oil. It is a good idea to have oil-filled pumps on an annual preventive maintenance schedule for oil change.

6.2.10.4 Oil Mist Eliminators

The exhaust of a rotary-vane pump is often fitted with an oil mist eliminator (filter). There are a variety of oil mist eliminators that may or may not include an inspection view port or replaceable filter element. If the eliminator is not serviced or replaced regularly, oil will exhaust from the pump. Consider scheduling service or replacement of the oil mist eliminator when the pump oil is changed.

6.2.10.5 Diaphragm Pumps

On smaller probe stations, diaphragm pumps can be used as fore pumps for the turbo pump; however, even on smaller probe stations, the seals in the pump wear down and should be replaced periodically. Always follow the manufacturer's recommendations to reduce potential down time.

6.2.11 Pumping out the Transfer Line

The transfer line requires regular service approximately every 12 months or whenever it becomes soft (section 6.3.2). More frequent service may be required when using liquid nitrogen, because nitrogen does not cryopump the line as well as helium.

An evacuation adapter is delivered with the transfer line to adapt the pump port on top of the transfer line to an appropriate vacuum pumping system. The transfer line should be pumped with a turbo pump. The Lake Shore Model PSV81-DP or equivalent pump you use to pump out the probe station vacuum chamber will be sufficient for this process. It is also recommended that you check the transfer line for leaks as it is pumped (if a leak detector is available), to eliminate the possibility that a leak is the cause of the poor vacuum.

If the necessary pumping and leak-checking equipment is not available on site, the transfer line can be sent back to Lake Shore for service. Otherwise, follow this procedure to pump out the transfer line.

1. Attach the evacuation adapter to the evacuation port on the transfer line (FIGURE 6-2).
2. Tighten the fitting nut using a 1¼ in wrench.
3. Attach one end of the vacuum line to the port on the vacuum system and the other end to the NW 16 evacuation adapter.
4. Push in the plunger on the evacuation adapter, and turn it clockwise approximately two turns to engage the plug. Do not force it, as you may strip the threads.
5. Start the vacuum and let it run for 5 min.
6. Pull the plug out to begin pumping out the transfer line.
7. Evacuate the transfer line for a minimum of 12 h. If the transfer line has been opened or vented, it may need to be pumped for several days, especially if it has been exposed to damp air.
8. Push the evacuation adapter plunger back in to reseat the plug into the transfer line.
9. Turn off and properly vent the pump.
10. Turn the plunger counterclockwise to disengage the plunger from the plug.
11. Using a 1¼ in wrench, remove the evacuation adapter from the transfer line.

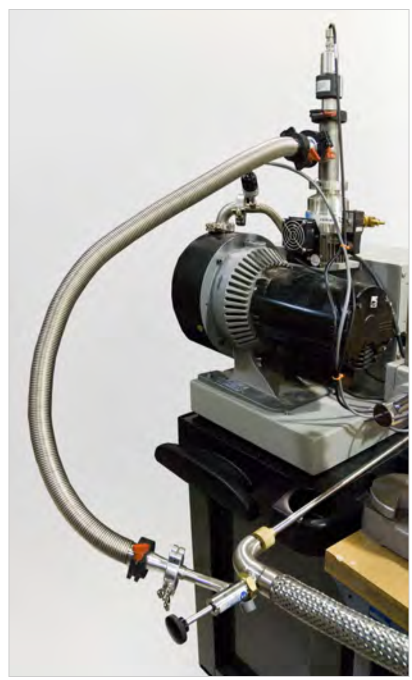


FIGURE 6-2

Top: Evacuation adapter attached to the evacuation port on the transfer line

Right: Pumping out the transfer line

6.2.12 Removing Condensation from Inside the Vacuum Chamber

Opening the vacuum chamber to atmosphere when the refrigerator is at cryogenic temperatures allows water vapor to condense on the refrigerator and freeze into ice. It is possible for the refrigerator or turbo vacuum pump to suffer irreparable damage when this occurs. It can take as long as a week to return the probe station to proper working order. The time is required because water molecules are easily attracted to the surfaces inside the probe station, such as the convolutions in the bellows, and it is difficult for the vacuum pump to remove them.

On some vacuum systems, this problem can be overcome through a “bake out” process. During bake out, the chamber is heated to increase the energy in the water molecules so they move away from the surfaces and can be pumped out more quickly. The CPX cannot be baked out because its components will not tolerate the high temperatures required. However, controlled warming and cycle purging can reduce the time it takes to recondition the vacuum chamber.

To dry out the vacuum chamber and check for damage, follow the procedures below:

1. If the refrigerator is still cold, close the purge valve and vacuum isolation valve to prevent more moisture from entering the system.
2. Turn off and properly vent the turbo pump. The turbo pump should not be used in this process until all visible water has evaporated from the chamber.
3. Allow all stages of the refrigerator to warm to room temperature (300 K). The temperature controllers can be used for warm up, but they should be monitored closely in case any of the sensors were damaged.

CAUTION

Never heat any part of the probe station refrigerator above room temperature unless the vacuum chamber is under vacuum.

4. Remove the chamber and radiation shield lids and sample holder.
5. Wait 24 to 48 hours for the system to dry until there is no visual condensation on the inside or outside of the vacuum chamber. A small fan or heat lamp may speed this step.
6. Reinstall the sample holder, radiation shield lids and vacuum chamber lid.
7. Using section 4.4.2 as a guide, evacuate the chamber.
8. Warm the refrigerator stages slightly above room temperature to help evacuate the water molecules. Monitor the stage temperatures closely until they stabilize in case any of the sensors were damaged. Stages should be warmed to the following temperatures:
   - Sample: 475 K
   - 4 K shield: 380 K
   - Radiation shield: 380 K
   - Second shield: 380 K

CAUTION

Do not allow the sample stage to exceed 475 K, the 4 K shield stage, radiation shield stage or the second radiation shield stage to exceed 380 K, or the probe arm to exceed 350 K. Temperatures exceeding this could cause damage to your probe station.

9. Use the vacuum pump to evacuate the probe station for 24 to 48 hours.
10. If the vacuum chamber can attain <10^{-3}Torr, then go to step 13.
11. Cycle purge the refrigerator several times with dry argon gas using the instructions in section 4.4.4 as a guide. Allow the argon gas to remain in the chamber for at least 30 min during each cycle before evacuating. Allow the vacuum pump to run for several hours during each cycle.
12. If the station can attain <10^{-3} Torr, then go on to step 13; if not contact the Lake Shore service department because the system may have a vacuum leak or other damage.

13. Use the procedures in section 3.6 to ensure basic functionality of the probe station and vacuum pump.

6.3 Troubleshooting Procedures

The following procedures should only be performed by skilled operators who are familiar with the required process and equipment. Damage to the probe station can result if these procedures are not done properly. If you require assistance, contact Lake Shore service or your local representative before beginning these procedures. Contact information is in section 6.5.

6.3.1 Vacuum Troubleshooting

The CPX should be able to achieve a vacuum of <10^{-3} Torr at room temperature with an appropriate vacuum system and the gauge located on the chamber. If your vacuum does not perform similar to the curve illustrated in FIGURE 6-3, the following sections describe some common problems and simple diagnostic procedures to remedy this. If the problem is caused by a very small leak it may be necessary to use a leak detector to troubleshoot it properly. Leak detector operation is not covered in this manual. Consult your leak detector user's manual.

Suspect poor vacuum if you observe any of the following symptoms:

- Refrigerator will not cool to base temperature
- Cooling time increases
- Condensation appears on sample surface
- Condensation appears on any internal viewport surface
- Excessive condensation appears on exterior of chamber viewport

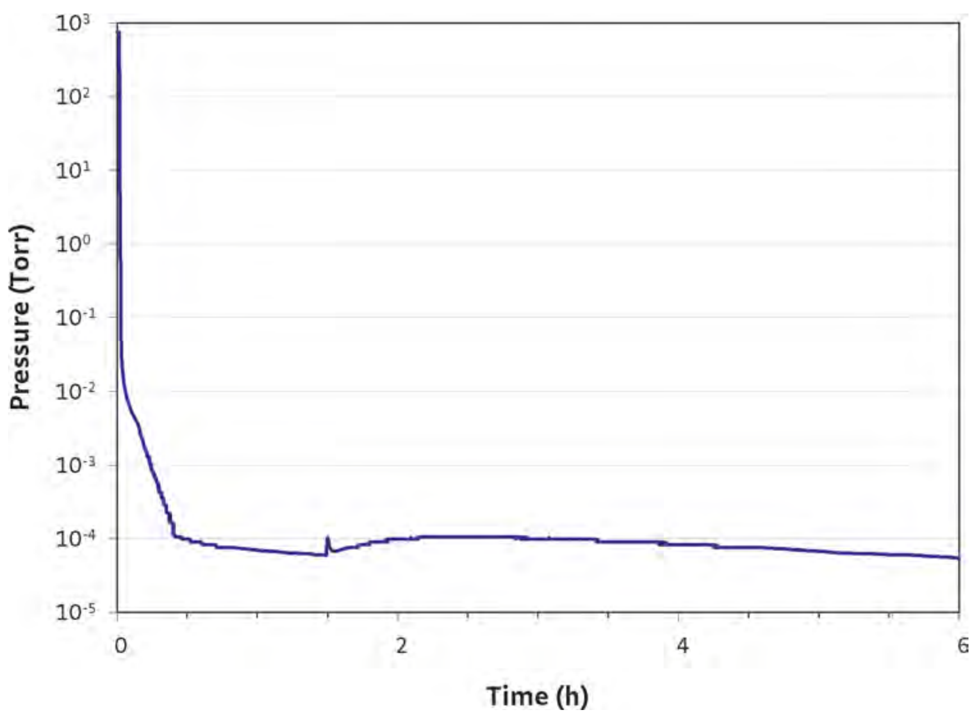


FIGURE 6-3 ***Typical CPX pump down curve***

6.3.1.1 Test the Turbo Vacuum Pump Alone

Before going through an extensive troubleshooting process on the probe station, it is advisable to verify proper pump and gauge operation. The only components needed for this step are the turbo vacuum pump and an NW 40 vacuum blank-off plate. The turbo vacuum pump must be equipped with an NW 40 inlet connection and a vacuum gauge capable of reading pressures down to 10^{-8} Torr.

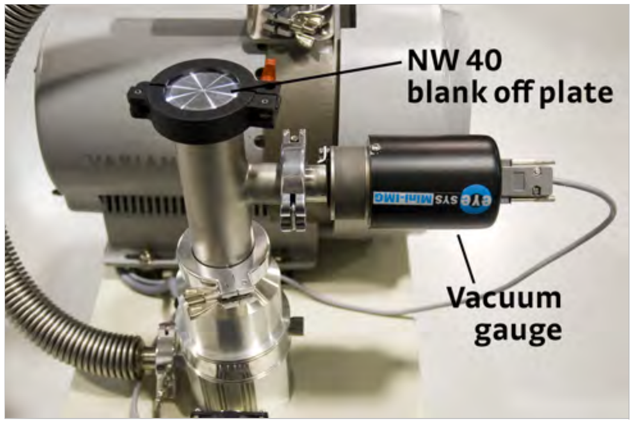


FIGURE 6-4 ***Turbo vacuum pump NW 40 connection, T and gauge***

1. With the gauge located on a T at the inlet of the vacuum pump, place the NW 40 centering ring, blank-off plate, and clamp over the inlet of the vacuum pump T.
2. Ensure the manual vent valve is fully closed.
3. Power on the pumping system. FIGURE 6-5 shows the PS-V81DP control panel. The steps to power on the pumping system are:
   a. Switch the main power rocker switch to the up position, which powers on the entire unit.
   b. Switch the scroll pump knob from position 0 to position 1 to start the roughing pump.
   c. Press the start button on the turbo pump controller to engage the turbo pump. If the controller is set in remote mode, the turbo pump will automatically start and stop with the scroll pump knob.

FIGURE 6-5 ***a. Main power rocker switch; b. Scroll pump knob; c. Start button***

4. The turbo vacuum pump should start rotating up to its maximum operational speed.
5. If the vacuum gauge readout is not currently displayed on the turbo controller front panel, push the measures button on the controller front panel to cycle through various pump diagnostics until the vacuum gauge readout is displayed.

The Eyesys Mini-IMG gauge reads pressures from 10^{-3} Torr down to 10^{-9} Torr, so there will be no vacuum pressure reading until the pressure has reached below 10^{-3} Torr.

6. If the connections are all made securely, the vacuum gauge reading should come down to <10^{-6} Torr within 10 min of pumping.
7. Do not continue to the next steps if this pressure is not achieved; contact Lake Shore or your vacuum pump manufacturer directly for technical assistance.
8. If 10^{-6} Torr is achieved, turn off the scroll and turbo pump:
   a. Press the stop button on the vacuum turbo pump controller to disengage the turbo pump.
   b. Switch the scroll pump knob from position 1 to position 0 to stop the roughing pump.
   c. Open the manual vent valve located on the side of the turbo pump to vent the turbo pumping system. You will hear hissing as the manual vent screw is opened and air rushes in to the turbo pump.
   d. Once the hissing ceases, completely close the manual vent valve.

NOTE **It is acceptable to leave the main power rocker switch in the on position when not operating the vacuum pumping system.**

6.3.1.2 Test the Vacuum Pumping System Along with the Connection to the Probe Station

1. Remove the NW 40 blank-off plate from the inlet T on the vacuum pumping system.
2. Set aside the NW 40 blank-off plate; it is no longer needed.
3. Use the NW 40 centering ring and clamp to connect the NW 40 flexible stainless steel vacuum line to the inlet T of the vacuum pumping system.
4. Fully close the vacuum isolation valve; in this step we are only checking the vacuum of the connection up to the probe station.
5. Power on the pumping system using steps 3a–3c in section 6.3.1.1.
6. Observe the vacuum gauge reading. If the connections are all made securely, the reading should come down to <10^{-5} Torr within 10 min of pumping.
7. Do not continue to the next steps if this pressure is not achieved; see section 6.3.1 or contact Lake Shore for technical assistance (see section 6.5 for contact information).
8. If 10^{-5} Torr is achieved, turn off the scroll and turbo pump, and perform steps 8a–8e in section 6.3.1.1 .

6.3.1.3 Test the Vacuum Pumping System, the Connection to the Probe Station and the Probe Station Vacuum Chamber

1. Leave the vacuum pumping system connected to the probe station as in the previous section.
2. Make sure that the vacuum pumping system is vented to atmosphere (use the manual vent valve on the side of the turbo pump), and the probe station vacuum chamber is vented to atmosphere (use the purge valve and procedure in section 3.4.3.1).
3. Open the vacuum isolation valve on the probe station vacuum chamber.
4. Power on the pumping system using steps 3a–3c in section 6.3.1.1.
5. If vacuum levels come down to <10^{-2} Torr within 10 min of pumping, you can assume all the connections are made securely.
6. If vacuum levels come down to <5×10^{-4} Torr within 1 h of pumping(with the gauge located on the T inlet of the vacuum turbo pump), you can assume all connections are made securely and there are no large leaks.
7. If vacuum levels come down to <5×10^{-5} Torr within 2 h of pumping, you can assume all connections are made securely, there are no large leaks and the chamber is free of moisture.
8. If the pressure listed in step 7 is achieved then you have verified that the vacuum pumping system and probe station vacuum chamber are functioning properly.

9. Continue through the remainder of section 6.3.1 and if these pressures are not achieved, contact Lake Shore for technical assistance.

6.3.1.4 The Impact of Cryopumping

Any time cryogen is flowing through the refrigerator, gas molecules in the chamber will freeze onto the cryogen-cooled surfaces (cryopump). An otherwise functioning probe station can cryopump well enough to overcome a poor initial vacuum or keep up with a very small leak for some time. Although this can be beneficial in some circumstances, it can also mask vacuum problems and create unexpected results such as condensation on the sample. The target vacuum levels in this section are all given with the assumption that the refrigerator is at room temperature because it is difficult to troubleshoot a vacuum leak when the refrigerator is cold.

6.3.1.5 Vacuum Chamber Leak Test

If you have achieved the pressures in section 6.3.1.1 and section 6.3.1.2, but have failed to achieve the pressures listed in section 6.3.1.3, follow this procedure and the procedures through the end of this section to identify vacuum integrity issues in your probe station. If a calibrated gauge is not available (for step 1), the gauge from the pump cart can be moved for this test as shown in FIGURE 6-6 .

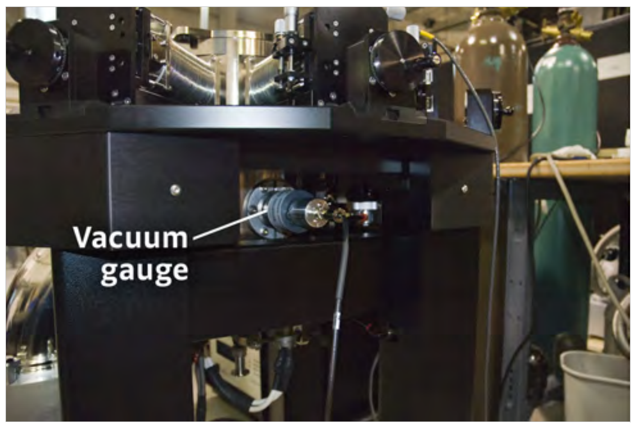


FIGURE 6-6 ***Vacuum gauge on the chamber***

1. Install a vacuum gauge on the chamber side of the vacuum isolation valve.
2. Pump out the vacuum chamber as described in section 4.4.2.
3. Allow the pump to run for 2 h.
4. Log the gauge reading at the chamber.
5. If the system did not reach <10^{-3} Torr, refer to section 6.3.1.6 to section 6.3.1.8.
6. Close the vacuum isolation valve.
7. Turn off the vacuum pump.
8. Wait 10 min; compare the gauge reading at the chamber to the reading recorded in step 4.
9. If the two readings are not the same order of magnitude, or the pressure reading continues to rise, there may be a leak in the vacuum chamber.

6.3.1.6 Will Not Achieve 10^{-2} Torr

If the system will not achieve at least 10^{-2} Torr in the vacuum chamber, the problem is likely mechanical and should be relatively easy to identify. Follow this procedure to find the issue.

- Close the purge valve
- Close the turbo vent valve if it is not closed automatically
- Check the alignment of the vacuum chamber lid
- Verify that the chamber lid o-ring is properly seated
- Verify that the seals and clamps are properly installed on the vacuum line

- Examine any changes that were made to the system since it was last used to verify that the system was reassembled properly
- Look for any parts that may have been damaged, including bellows, vacuum line, valves, fittings, etc.

6.3.1.7 Will Not Achieve 10^{-3} Torr

Systems achieving between 10^{-2} Torr and 10^{-3} Torr in the vacuum chamber can be more difficult to troubleshoot because these smaller leaks can be hidden.

- Examine any changes that were made to the system since it was last used (especially removal of probe arm assemblies) to verify that the system was reassembled properly. Remove, clean, inspect for damage, grease, and reinstall o-rings that were used in the change.
- Remove, clean, inspect for damage, grease, and reinstall the vacuum chamber lid o-ring. Make sure the o-ring is not twisted.
- Check the torque on fasteners between the bellows and arm base; see section 5.3.4. Do not overtighten these fasteners or new leaks can be created.
- As an aid in identifying the source of the leak, place a few drops of isopropyl alcohol on the suspected area and look for an observable change in the vacuum gauge reading.

6.3.1.8 Will Not Achieve Less Than 10^{-3} Torr or Cool to 4.2 K

Systems capable of achieving 10^{-3} Torr, but unable to achieve and hold between 3×10^{-4} Torr and 9×10^{-4} Torr or unable to cool to a base temperature of 4.2 K, are the most difficult to troubleshoot, because the symptom can be caused by several different problems. Contamination in the vacuum chamber and very small leaks are the most common issues associated with this level of performance.

Suspect contamination if:

- The system has been left open for extended periods of time
- The system has been worked on and good vacuum practices were not followed
- The system has been overheated or operated when not under vacuum
- The system has been vented to atmosphere while cold

To minimize the effects of contamination:

- Follow the guidelines in section 6.2.3
- Follow the guidelines in section 6.2.12

Suspect a very small leak if:

- The pump passed a blank off test
- The system is clean and poor vacuum persists
- Performance degrades the longer the system is cold
- Sudden changes in vacuum reading are observed when the sample stage is heated, especially warming above 77 K

The best way to proceed if you suspect a leak:

- Follow the instructions in section 6.3.1.7 in hopes of sealing the system even if the exact source is not identified
- Replace any o-rings that look worn or flattened
- Clean and lubricate the o-rings (section 6.2.5.2) in the micrometer valve stem, especially if the leak increases when the valve is actuated
- Clean and re-grease the o-rings between the probe arm base and bellows, especially if the leak increases when planarization adjustments are made
- If the pressure relief valve assembly activates routinely, verify that it reseats properly

WARNING **Never operate the probe station without a pressure relief valve installed.**

If these troubleshooting procedures do not correct the problem, a helium leak detector will be required to identify the exact source of the leak.

6.3.2 Transfer Line Troubleshooting

Transfer line problems most often fall into three categories: the transfer line becomes soft, it becomes plugged, or the foot valve control knob freezes and will not operate.

6.3.2.1 Soft Transfer Line

The transfer line may have become soft if any of the following symptoms are observed:

- Reduced gas output from the transfer line
- Cooling time increases
- Cryogen consumption increases
- Transfer line starts to become noticeably cooler during operation
- Condensation appears on the braid during operation (condensation and frost is normal near the bayonet fitting)

If the transfer line is soft, it requires maintenance as described in section 6.2.11. If the transfer line requires pumping more than every three to six months when using helium, or more than two to three months when using nitrogen, it may have a leak. Contact Lake Shore service or your local representative for assistance.

If there is a single cold spot on the transfer line after it is pumped out, there may be a physical touch between the inner line and the outer vacuum jacket of the transfer line. In this case, contact Lake Shore or your local representative.

6.3.2.2 Plugged Transfer Line

Suspect a plugged transfer line if it will not generate a cryogen plume when pre-cooled as described in section 4.5.3.2. The most common cause of a plugged transfer line is an ice blockage; however, the bayonet end of the transfer line is susceptible to being plugged with foreign material.

The transfer line attracts water vapor from the air any time it is colder than its surroundings. Any time that water vapor is allowed inside the line, it will freeze and form an ice blockage. The operating instructions in Chapter 4 are intentionally sequenced to minimize this risk, but ice blockages can still happen. They are especially common when working in high humidity, pre-cooling with nitrogen, or changing helium Dewars during operation. All of these cases expose the transfer line to greater than normal ice build-up.

The best defense against an ice blockage in the transfer line is:

1. Open the foot valve control knob six turns before inserting it into the Dewar.
2. Use a heat gun to melt excessive ice off of the bayonet end before inserting it.
3. Allow the transfer line to warm up and dry out after each use before cooling again.

If the transfer line becomes blocked with ice:

4. Remove it from the bayonet and the Dewar.
5. Allow it to warm to room temperature.
6. Pass low pressure, dry nitrogen gas through the line until it is dry.

Repeated ice blockage in the transfer line may indicate excessive contamination in the Dewar itself. Water vapor and other gas can contaminate the cryogen if the Dewar is not maintained properly. Dewars should be stored under positive pressure, pressurized only with dry, pure gas and decontaminated before refilling.

If the transfer line remains plugged after it has been warmed and dried, the blockage may be from another cause. The transfer line target-side leg is tapered to properly engage the bayonet on the probe station. The taper is perfectly shaped to pick up plaster, paint or other foreign material if the transfer line is bumped into walls or equipment in the lab. Inspect the bayonet end of the transfer line. If it is blocked, remove the debris with a wooden toothpick; never use a metal tool. If the end is bent or otherwise damaged, contact Lake Shore service or your local representative for assistance.

6.3.2.3 Stuck Foot Valve Control Knob

The foot valve control knob on the transfer line can become stuck if the foot valve is blocked with ice. It can also become stuck if the transfer line is inserted into a Dewar with the valve closed completely.

CAUTION

Do not force the foot valve control knob when it is stuck. This can damage the delicate foot valve.

Ice build-up in the foot valve has the same causes as described in section 6.3.2.2. Follow the same instructions to remedy and prevent the foot valve from freezing . Remember, the transfer line must be removed from the Dewar to melt the ice because the foot valve is at the bottom of the transfer line supply leg. Heating the foot valve control knob at the top will not help.

The foot valve can also become stuck if the transfer line is inserted into a Dewar with the valve closed. Thermal contraction of the valve parts can jam the valve. The remedy is the same as for an ice blockage: remove, warm, open, and reinsert the transfer line.

6.3.3 Refrigerator Cooling Troubleshooting

Many refrigerator cooling issues are actually symptoms of vacuum problems or transfer line problems. It is advisable to review section 6.3.1 and section 6.3.2 before proceeding with this section. The most common refrigerator cooling problems are listed below.

6.3.3.1 Refrigerator Does Not Begin to Cool

Use this section if neither the sample stage nor 4 K shield stage begin to cool. The first step is to make sure that all temperature controller heater loops are turned off or have a 0 K setpoint. Both the Model 332 and 340 have two control loops. If this has been verified, then the problem is most likely with the Dewar or transfer line. If the cryogen transfer is initiated and it does not create a plume (FIGURE 4-14), check for the following common problems:

- Insufficient Dewar pressure
- Dewar empty
- Transfer line not reaching cryogen in the Dewar
- Transfer line foot valve closed
- Transfer line plugged

If the cryogen transfer is initiated and creates a plume as shown in FIGURE 4-14, the problem is more likely a blockage in the refrigerator itself. If the refrigerator becomes blocked with ice:

- Remove the transfer line
- Allow the refrigerator to warm to room temperature
- Pass low pressure, dry nitrogen gas through until it is dry

6.3.3.2 Sample Stage Will Not Cool

If the 4 K shield stage cools but the sample stage does not, there are two potential problems that are easy to remedy and should be checked first:

- Micrometer valve is not opened sufficiently
- Sample stage temperature control is on

If you have the micrometer valve open sufficiently and the sample stage temperature control is off, then your problem may be a result of the following:

- Sample stage warmer than 4 K shield stage—when the 4 K shield stage is cold and the sample stage remains above 100 K it can become difficult for cryogen to enter the sample stage cooling line—refer to step 7 in section 5.2.1 for instructions on how to use the exhaust valve assembly to aid in cooling the sample stage
- Sample stage cooling line is blocked with ice—follow the instructions in section 6.3.3.1 to remove ice blockage

6.3.3.3 4 K Shield Stage Will Not Cool

If the sample stage cools but the 4 K shield stage does not, there are two potential problems that are easy to remedy and should be checked first:

- Exhaust valve not open
- Temperature control was left on for either the 4 K shield stage or radiation shield stage after the refrigerator was warmed up to room temperature

There are also two potential problems that require more time to remedy:

- The 4 K shield stage cooling line is blocked with ice—follow the instructions in section 6.3.3.1 for removing ice blockage
- Cooling with nitrogen—when cooling with nitrogen it is important to open the micrometer valve, allowing cryogen to flow to the sample stage while cooling the 4 K shield stage (this operation seems counterintuitive, but it is effective)

6.3.3.4 Sample Stage Does Not Reach 4.3 K Base Temperature

The sample stage should be able to cool to 4.3 K within 10 min after the radiation shield cools and stabilizes. A large number of problems can prevent the sample stage from reaching base temperature, because every subsystem needs to be optimized simultaneously. Common problems are:

- Poor vacuum
- Soft transfer line
- Insufficient cryogen flow—foot valve or micrometer valve not open sufficiently
- Insufficient Dewar pressure—pressure less than 21 kPa to 28 kPa (3 to 4 psi) will not provide enough cryogen to the refrigerator
- Excessive Dewar pressure—pressure greater than 34 kPa (5 psi) will raise the temperature of the cryogen in the Dewar
- Probe arm position—placing probe arms in the fully retracted x-axis position presents a greater heat load, as more of the arm's length will be outside of the radiation shielding—extend the probe arms into the probing area to reduce the heat load
- Extra heat load on the sample stage—can be caused by arm braids touching improperly, temperature control heater left on, microscope light left on, or all probe arms positioned all the way out in the x-axis
- Improper temperature controller setup—if the temperature controller inputs are reconfigured, it is common for the wrong temperature response curve to be selected for a sensor

6.3.3.5 Takes Too Long to Cool

FIGURE 6-7 illustrates a typical CPX refrigerator cooling curve for helium. The system cools slowly at first because the heat capacity of the materials is high near room temperature. As the materials cool, their heat capacity drops and the system cools more quickly. This impacts warm up time and temperature control time constants. Please note that cooling with nitrogen takes significantly longer than cooling with helium.

If the cooling cycle takes significantly longer than the times represented in the cooling curve (FIGURE 6-7), investigate the possible causes listed in section 6.3.3.2 to section 6.3.3.4. In addition, be sure to pre-cool the transfer line as shown in FIGURE 4-14.

NOTE **The cooling curve pictured below was performed following the procedure given in section 5.2.1. The sample stage cooldown was purposely cooled slowly, allowing the radiation shields to cool first so that the majority of residual gas was attracted to them and not the sample.**

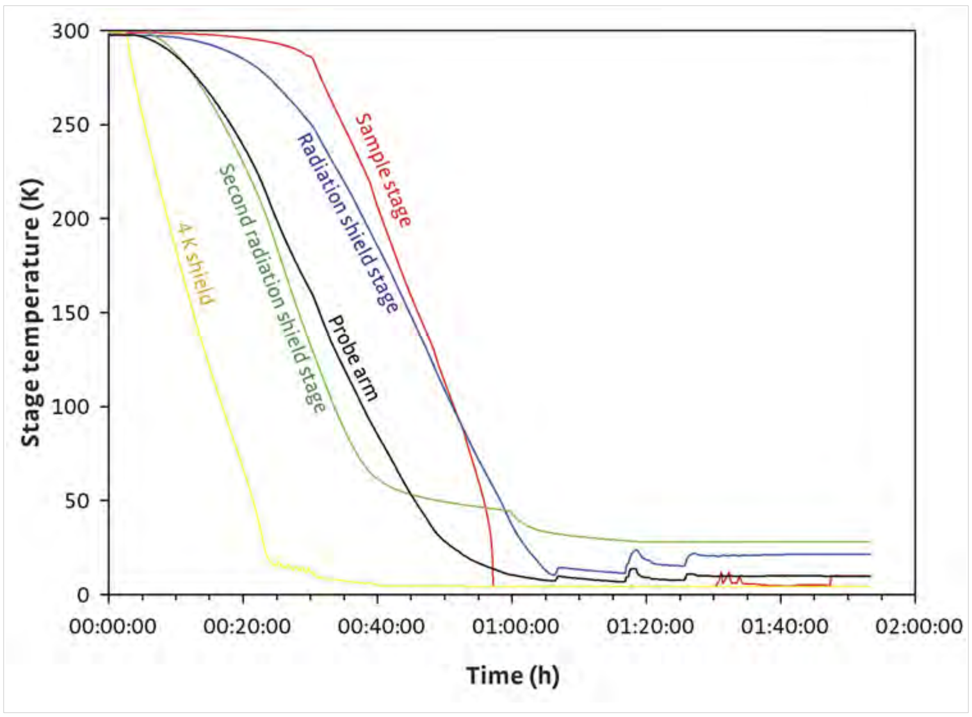


FIGURE 6-7 ***Typical CPX refrigerator cooling curve for helium***

6.3.3.6 Micrometer Valve Problems

The most common problems with the micrometer valve are that it can become stuck or difficult to turn. In either case, the valve should never be forced open or closed because it can be easily broken.

Cooling the system with the valve closed completely can cause it to stick as the valve body contracts around the stem. Operating instructions always specify opening the valve before cooling. If the valve does become stuck, the refrigerator must be warmed before the valve can be opened. Warming the valve handle will not help because the valve body is inside the refrigerator, not near the handle.

6.3.3.7 Erratic Temperature Readings

The CPX sample stage is a stable temperature control platform and reasonable temperature control can be achieved over the entire temperature range. Short term temperature control of a few tens of millikelvins should be expected around base temperature. As the system approaches maximum temperature, short term control stability degrades somewhat, but should remain below 1 K in a properly tuned system. Long term stability is very dependent on consistent helium flow, which requires well regulated Dewar pressure.

Considerations when regulating with mechanical flow controls

When operating at or near base temperature, the mechanical flow controls are used to regulate temperature. At these temperatures, electronic temperature control is not appropriate, because there is insufficient cooling power for the controller to work against.

The following problems may cause unstable or erratic temperature readings to occur when controlling with mechanical flow controls:

- Change in Dewar pressure—this can be caused when there is not adequate regulation of the pressurizing gas source, or if you rely on a pressure relief valve to regulate Dewar pressure
- Shield stages not stabilized—sample stage temperature will not regulate properly until the shield stages stabilize
- Irregular cryogen flow—there can be a combination of control settings that cause irregular cryogen flow through the refrigerator. If this condition occurs, the exhaust gas pressure will oscillate with a period of between ten seconds and a few minutes and the exhaust port sounds as if it is breathing. The oscillations almost always settle out when the refrigerator reaches temperature equilibrium. If not, choose a different Dewar pressure or foot valve operating point and re-establish control.

Considerations when regulating with electronic temperature controls

When operating with the electronic temperature controllers the following problems may cause unstable or erratic temperature readings.

- Controller PID parameters are not tuned properly—the controller tuning parameters listed in TABLE 4-4 are a good starting point, but may need to be modified to achieve optimum control stability based on specific measurement conditions. Heater range is important to tuning and also must be set properly.
- Controlling too close to base temperature—attempt to control a few kelvin higher in temperature, then gradually lower the setpoint to identify the lowest practical electronic control temperature
- Electrical noise—ground loops and other electrical noise can impact the controller's temperature readings

6.3.4 Image System Troubleshooting

Establishing a high quality sample image can be difficult the first time the probe station is set up or after it has been reconfigured if the proper setup is not followed. The electrical, mechanical and optical components of the vision system must all be working together properly for the vision system to perform as expected. This section will help identify which part of the vision system is causing the undesirable symptom so it can be remedied.

6.3.4.1 No Image

If there is no image on the monitor at all, the problem is likely electrical. It is important to remember that the camera, light source and monitor are independent components and have separate power supplies and power switches.

- Remove lens cover if present

- Verify the camera, light source and monitor are all powered and turned on
- Turn the light source to 50% output
- Verify that the s-video cable between the camera and monitor is plugged in
- Verify the monitor source is set to the s-video input

If the problem is not identified with these steps, press the set (setup) button on the camera. If the setup menu appears on the monitor, the problem is likely in the optics rather than the electronics. The following sections may help identify the problems with image system optics.

6.3.4.2 Insufficient Sample Illumination

Typically no more than 50% to 70% of the maximum light source setting is required to properly illuminate the sample. If a higher output is required or the sample remains too dark at 100% output, the light source may be out of alignment. To verify proper alignment, do the following:

- Turn off the light source and allow it to cool
- Remove the fiber optic bundle from the light source
- Remove any dust on the end of the fiber optic bundle
- Check that the bulb is centered in the opening

If the bulb is out of alignment, refer to the light source manual for further information.

NOTE **Do not lower or raise the microscope trying to improve illumination. This will bring the sample out of the focal range of the microscope.**

6.3.4.3 Poor Image Quality

Troubleshooting poor image quality can be challenging because the symptoms of a variety of problems are very similar. The next four sections cover a variety of image quality issues. The first three (section 6.3.4.4 to section 6.3.4.6) are more likely to cause a blurred image that appears to have good color and contrast but does not focus sharply. The causes listed in these sections are relatively easy to diagnose and should be checked first. Low contrast images are explained in section 6.3.4.7. This problem is the most difficult to diagnose and is often related to the sample surface and the light source chosen for the system.

6.3.4.4 Fog on the Viewport

Fog normally indicates that the viewport window needs to be cleaned with an appropriate anti-fog solution; see section 6.2.4. In severe cases, persistent fogging can indicate poor chamber vacuum; see section 6.3.1. When checking for fog, also check for smudges on the microscope lens or on any of the viewports and clean as needed (section 6.2.4).

6.3.4.5 Height Adjustment

The range of focus of the microscope is quite short, as small as 34 μm on some systems. It is common for a microscope that is set up for thick samples to be incapable of focusing on the sample holder or thin samples.

Follow this procedure if the microscope does not focus on the sample surface:

1. Set the microscope focus knob to the middle of its range.
2. Loosen the nylon thumbscrew on the horizontal boom.
3. While supporting the microscope with one hand to prevent it from falling, use the 3⁄16 in hex driver to loosen the shaft collar (section FIGURE 6-8).
4. Slide the microscope and collar up or down a few millimeters and tighten the shaft collar and thumbscrew.
5. Attempt to focus again.
6. Continue adjusting the height until the sample can be focused.

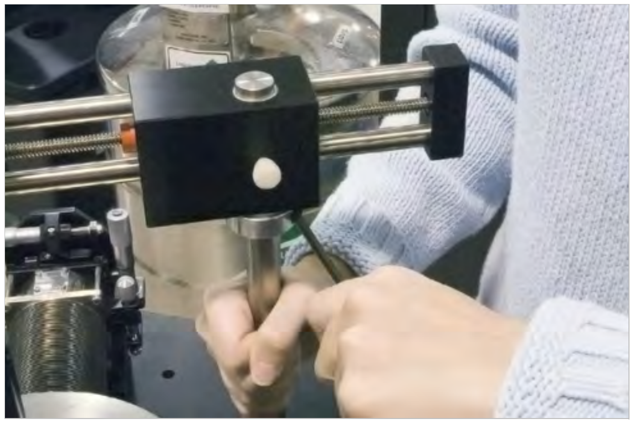


FIGURE 6-8 ***Microscope focus adjustments***

6.3.4.6 Vibration in the Image System

The most common reason for a blurred image on a properly focused microscope is vibration. Vibration can come from many sources including vacuum pumps, motors, and fans running in the vicinity of the probe station.

Vibrations can also affect the microscope directly. Make sure the electrical wires and fiber optic bundle going to the microscope are not stretched tight and do not pass over the vacuum line or any other vibration source. Isolate the light source from the probe station to verify its fan is not causing the blurred image. Finally, verify that the nylon set screw is tight on the shaft.

Vibration from vacuum pumps: vacuum pumps used with the probe station are a likely candidate for vibration because they are in close proximity to the probe station and are connected through stainless steel lines that transfer vibration. Vacuum pumps and lines can be easily identified as the source of vibration by observing the microscope image when the pumps are off and lines disconnected. If a pump or line is identified as a problem and it cannot be disconnected during operation, the PS-PLVI-40 pump line vibration isolation option is recommended.

Vibration from infrastructure: if the vibration is intermittent, it may be due to infrastructure sources such as HVAC systems or elevators. In this case, make sure that any vibration isolation options ordered with the probe station are properly installed and operating. If the system did not include active vibration isolation, it should be considered.

6.3.4.7 Poor Contrast Images

This section addresses images that are poor in contrast, show little or no sample definition and have little response to small changes in light intensity. This problem is difficult to troubleshoot primarily because of the geometry of the CPX itself. The relatively long distance between microscope and sample and two optic viewports in between offer significant challenges to conventional image systems. Because of this, the light source and sample surface can have a big impact on image quality.

The first step to remedy the problem is to eliminate other possibilities. The steps below assume you have warmed the system to room temperature.

1. Using the camera setup menu, reset the camera controls to their factory preset values.
2. Remove the vacuum chamber lid and radiation shield lids.
3. Re-establish the sample image with the lids off.

This should provide an image with very high quality and contrast. If it does not, go back through the assembly procedures, section 3.4.2, and the earlier parts of section 6.3.4 and try to identify the problem.

NOTE **The image obtained with the chamber and shield lids off is better than can be expected with them on. The viewport optics will always degrade image quality no matter how well the system is optimized.**

Experiment with different sample materials first with the lids off, then add the lids back on one at a time. First try a very reflective sample such as a piece of polished silicon wafer. Then experiment with a sample that absorbs light. Finally, try a sample that has high contrast and image on the three dimensional details in the sample holder itself. This investigation will establish the limits in capability of the probe station and its configuration of microscope and light source.

Optimize the light intensity and camera settings for the type of sample most commonly tested in the probe station. If the results do not meet expectations for the equipment purchased, contact Lake Shore service for assistance (section 6.5).

6.3.4.8 Image Orientation

Follow this procedure to change the orientation of your image:

1. Below the threaded joint to the CCD camera is a rotating joint. Using a ⁵⁄₆₄ in hex driver, loosen the three set screws on this joint (FIGURE 6-9).
2. Rotate the camera so the image on the monitor is oriented logically. The objective is to rotate the camera until the monitor image corresponds to the expected image (the bottom left probe appears in the bottom left of the monitor screen).
3. Retighten the set screws after adjustment.

FIGURE 6-9 ***Loosening the camera rotating joint to adjust the camera image orientation***

6.3.5 Probe Troubleshooting

The three most common issues that arise with probes fall in three categories: bent or broken probe tips, poor or non-ohmic electrical contact, or a loss of continuity.

6.3.5.1 Bent or Broken Probe Tips

Probe tips by nature are delicate and must be handled with care both inside and outside the probe station. The following are ways that probe tips can be broken or bent:

Landing: landing probes is probably the most important step in achieving reliable, repeatable electrical measurements. Too little contact pressure will result in unstable measurements, but too much will damage probes. ZN50 probe tips damaged during landing are often bent upwards. Carefully follow instructions in section 4.6.2 to prevent probe damage. Develop and follow a protocol suitable for the combination of probe type and pad material used in each application.

Failing to raise the probe tips: the cautions throughout this manual instruct operators to raise probe tips before cooling or warming the system, when applying field or applying vacuum, and when moving probes in the x or y direction. Probes that are damaged when vacuum is applied or while being moved when landed are generally the ones that are very severely damaged. Probes damaged during temperature change often take on a characteristic curled shape. Wait for the probe arm temperature to stabilize, approximately 10 to 15 min after the 4 K shield stage stabilizes, before landing the probes.

Storing: when probes are not being used, store them in their original packaging. This is especially important for microwave probes, because the weight of the probe body will cause damage to the tip if the probe is left loose.

Cleaning: aggressive cleaning can easily damage probes. If more than periodic tarnish removal for the BeCu ZN50 probes is necessary, it is recommended to gently clean the probe tips under a microscope, working away from the probe body.

6.3.5.2 Poor or Non-Ohmic Electrical Contact

There are several important considerations for assuring good electrical contact between the probe and sample:

Pressure: appropriate contact pressure is required for both establishing and maintaining good contact. Too little pressure may result in high contact resistance, resistance that changes significantly with time or is overly sensitive to vibrations. Too much pressure will obviously cause probe damage. One way to ensure repeatable contact pressure is to monitor the distance the probe tip skates when being landed as described in section 4.6.2. This distance is likely different for each different probe material, tip radius and sample material. Another approach is to monitor the DC resistance of each pair of probes while landing.

Tip radius: a larger tip radius normally provides a larger area of contact, which consequently lowers contact resistance. The larger tip can also tolerate slightly higher pressure before being damaged. Smaller tips are normally chosen for probing smaller features, but they can also be useful in scratching through electrically insulating oxide layers that may form on the sample surface. For more information, please reference section 2.4.8.

Tip material: Lake Shore offers several tip materials for different applications. Not every tip material is compatible with every sample material. For more information, please reference section 2.3.2.1.

Dirty or damaged tips: some tip materials, especially BeCu, form an insulating oxide when exposed to air. Tips also get dirty during normal use. Bent or damaged tips generally make very poor electrical contact. Clean and inspect probe tips for damage regularly. For more information, please reference section 6.2.7.

Temperature change: probe arms change length when their temperature changes, necessitating lifting probe tips before changing temperature. The probe arms must stabilize in temperature for approximately 10 to 15 min (in addition to the sample stage) before probes can be landed effectively. If probes are landed too soon, the position of the probe tip will shift, degrading the quality of electrical contact.

6.3.5.3 Loss of Continuity

Loss of continuity is nearly always caused by bad contact between the probe tip and sample. If the contact resistance is known to be good and there is no continuity between the signal connector and the probe, the cause is likely a broken center conductor in the probe cable. This is often caused when the back of the SMA plug on the cryogenic coaxial cable is not held steady when the ZN50 probe is installed. Check the continuity of the center conductor by measuring the resistance between the center pin of the signal connector and the center of the SMA connector. If the resistance is not approximately zero, the cable must be replaced. Refer to section 5.3.5 for the procedure to replace the cable.

6.4 Service Reference

This is the service reference section.

6.4.1 Power Requirements and Power Configuration Information

Electrical power is required for the operation of the instrument console, vision system, turbo pumping system and air compressor (if used for the vibration isolation system). Most equipment is designed to operate over a range of line voltages. Some equipment must be configured to operate at a specific voltage within the range listed. This equipment is pre-configured at Lake Shore to the voltage specified when it is ordered. If the probe station is to be operated using a voltage other than the original configuration, some items may be reconfigured in the field while others may not. In addition, some items operate over the entire voltage range without modification. Field configurable options are indicated in TABLE 6-2. Refer to the equipment's user manual for more information.

Item		Voltage ranges (VAC)	Voltage tolerance	Power (W)	Frequency range (Hz)	Voltage input field configurable?
Instrument Console	Lake Shore Model 332 temperature controller	100 120 220 240	+6% -10%	150	50 to 60	Yes
	Lake Shore Model 340 temperature controller	100 120 220 240	+6% -10%	190	50 to 60	Yes
	Lake Shore Model 142 amplifier	100 120 220 240	—	750	50 to 60	No
Vision System	Viewera V172SV monitor	100 to 240	—	432	50 to 60	Universal
	Costar SI-C400N color CCD camera	100 to 240	—	96	47 to 63	Universal
	Microtech A20500 light source	100 to120	—	190	50 to 60	No
	Microtech A20510 light source	220 to 240			50 to 60	
Turbo Pumping System	Varian V81 AG-rack controller	100 to 240	—	210	50 to 60	Universal
	Varian SH-100 dry scroll vacuum pump	100 to 115 200 to 230	—	1084	50 to 60	Yes
Air Compressor	Central pneumatic #47407	120	—	264	60	No

TABLE 6-2 ***Detailed power requirements***

6.4.2 Pin Outs

The pin outs for the control and readout cables of the system are detailed in TABLE 6-3.

Cable	Connector	Pin	Color[a]	Function	Pin	Connector
DC0723	19-pin connector (bottom vacuum flange)	A	Red	V+	4	**Sample Sensor 1**[b] 6-pin DIN
		B	Black	V–	2	
		C	White	I+	5	
		D	Green	I–	1	
		No connection	Gray (tin)	Cable shield	3	
		E	Red	+	Signal	**Sample Heater 1** Dual banana
		F	Black	–	Ground	
		Connector body	Gray (tin)	Ground	Signal[c]	**Sample** Single banana
		G	Red	V+	4	**4 K shield Sensor 2** 6-pin DIN
		H	Black	V–	2	
		J	White	I+	5	
		K	Green	I–	1	
		No connection	Gray (tin)	Cable shield	3	
		L	Red	+	Signal	**4 K shield Heater 2** Dual banana
		M	Black	–	Ground	
		Connector body	Gray (tin)	Ground	Signal[c]	**4 K shield** Single banana
		N	Red	V+	4	**Rad shield Sensor 3** 6-pin DIN
		P	Black	V–	2	
		R	White	I+	5	
		S	Green	I–	1	
		No connection	Gray (tin)	Cable shield	3	
		T	Red	+	Signal	**Rad shield heater 3** Dual banana
		U	Black	–	Ground	
		Connector body	Gray (tin)	Ground	Signal[c]	**Rad shield** Single banana
		V	—	Not used**	—	—
DC2048	6-pin connector (bottom vacuum flange— second shield)	A	Red	V+	4	**Second shield** 6-pin DIN
		B	Black	V–	2	
		C	White	I+	5	
		D	Green	I–	1	
		No connection	Gray (tin)	Cable shield	3	
		E	Red	+	Banana+	**Second shield** Dual banana
		F	Black	–	Banana–	
		Connector body	Gray (tin)	Ground	N/A[c]	**Second shield** Single banana
DC0616	Probe arm 6-pin connector	A	Red	V+	4	**Probe arm sensor** 6-pin DIN
		B	Black	V–	2	
		C	White	I+	5	
		D	Green	I–	1	
		No connection	Gray (tin)	Cable shield	3	
		E–F	—	Not used	—	—

a. In control cable
b. Sample sensor (depending on model) either TG (GaAlAs) diode or Cernox™ thermometer
c. Drain wire connected to single banana, which plugs into chassis next to heater output of controller. The other end of the drain wire is connected to the body of the 19-pin mating connector.
***Both leads of a spare sample stage heater are tied to this pin.*

TABLE 6-3 ***Pin outs for the control and readout cables of the system***

6.4.3 Instrumentation Wiring Diagram

FIGURE 6-10 shows the system wiring diagram. It details the electrical interconnections between the probe station and instrument console. Lake Shore part numbers of individual cables are also shown. Contact Lake Shore if you need replacement cables.

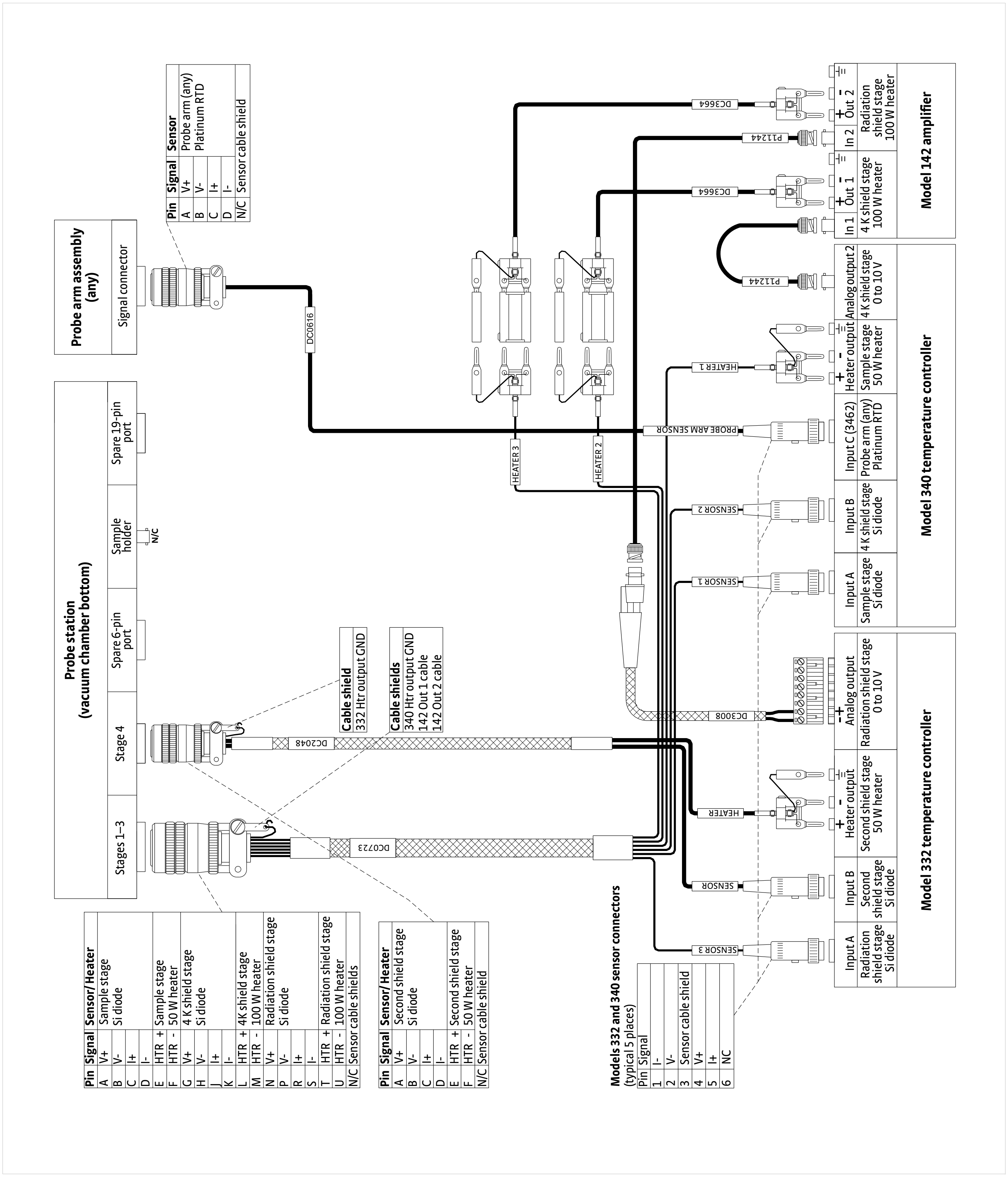


FIGURE 6-10 ***Wiring diagram***

6.5 Technical Inquiries

Refer to the following sections when contacting Lake Shore for application assistance or product service.

6.5.1 Contacting Lake Shore

The Lake Shore Systems Service department is staffed Monday through Friday between the hours of 8:00 AM and 5:00 PM EST, excluding holidays and company shut down days.

Contact Lake Shore Systems Service through any of the means listed below. However, the most direct and efficient means of contacting is to complete the online service request form at http://www.lakeshore.com/sup/serf.html. Provide a detailed description of the problem and the required contact information. You will receive a response within 24 hours, or the next business day in the event of weekends or holidays.

If you wish to contact Systems Service by mail or telephone, use the following:

Lake Shore Cryotronics, Inc.
575 McCorkle Blvd.
Westerville, Ohio 43082 USA
Phone: 614-891-2243 (option 6)
Fax: 614-818-1608
e-mail: sysservice@lakeshore.com

6.5.2 Return of Equipment

The probe station is packaged to protect it during shipment. Please use reasonable care when removing it from its protective packaging and inspect the probe station carefully for damage. If it shows any sign of damage, please file a claim with the carrier immediately. Do not destroy the shipping container; it will be required by the carrier as evidence to support claims. Call Lake Shore for return and repair instructions.

All equipment returns must be approved by a member of the Lake Shore Systems Service department. The service engineer will use the information provided in the service request form and will issue a Return Material Authorization (RMA). Once the RMA has been approved, you will receive appropriate documents and instructions for shipping the equipment to Lake Shore.

You will be given an RMA number. This number is necessary for all returned equipment. It must be clearly indicated on both the shipping carton(s) and any correspondence relating to the shipment.

NOTE **The user should retain any shipping carton(s) in which equipment is originally received, in the event that any equipment needs to be returned.**

6.5.3 RMA Valid Period

RMAs are valid for 60 days from issuance; however, we suggest that equipment needing repair be shipped to Lake Shore within 30 days after the RMA has been issued. You will be contacted if we do not receive the equipment within 30 days after the RMA is issued. The RMA will be cancelled if we do not receive the equipment after 60 days.

6.5.4 Shipping Charges

All shipments to Lake Shore are to be made prepaid by the customer. Equipment serviced under warranty will also be returned shipping prepaid by the customer. Equipment serviced out-of-warranty will be returned FOB Lake Shore.

6.5.5 Restocking Fee

Lake Shore reserves the right to charge a restocking fee for items returned for exchange or reimbursement.

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